Naval Education And Training Program Management Support Activity

GAS TURBINE SYSTEM TECHNICIAN (ELECTRICAL) 3 & 2

NAVEDTRA 10550-1

1985 Edition Prepared by
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The terms training manual (TRAMAN) and nonresident training course (NRTC) are now the terms used to describe Navy nonresident training program materials. Specifically, a TRAMAN includes a rate training manual (RTM), officer text (OT), single subject training manual (SSTM), or modular single or multiple subject training manual (MODULE); and a NRTC includes nonresident career course (NRCC), officer correspondence course (OCC), enlisted correspondence course (ECC) or combination thereof.

Although the words "he," "him," and "his" are used sparingly in this manual to enhance communication, they are not intended to be gender driven nor to affront or discriminate against anyone reading this text.

PREFACE

Gas Turbine System Technician (Electrical) 3 & 2, NAVEDTRA 10550, is a 12 chapter rate training manual (RTM). This RTM in combination with the nonresident career course (NRCC), NAVEDTRA 80550, provides training for all personnel preparing for advancement to GSE3 and GSE2.

The primary purpose of training is to produce a combat ready Navy which can guarantee victory at sea. This victory depends upon the state of readiness of the shipboard personnel and their ability to perform assigned tasks required to meet shipboard needs. This RTM provides information related to the tasks assigned to GSE third and second class petty officers. These tasks are required to maintain the ship's engineering plant and to contribute to the comfort of the crew. When we have personnel who can perform these tasks efficiently, the end result is a ship operating at a high state of readiness. When you are assigned duties aboard ship as a GSE3 or GSE2, you will be expected to know and understand the information contained in this manual. The degree of success of the Navy will depend in part on your ability and the manner in which you perform your assigned tasks.

Gas Turbine System Technician (Electrical) 3 & 2, NAVEDTRA 10550, was prepared by the Naval Education and Training Program Development Center, Pensacola, Florida, for the Chief of Naval Education and Training. Technical assistance was provided by Naval Sea Systems Command; Service School Command, Great Lakes, Illinois; Naval Surface Warfare School, Newport, Rhode Island; PQS Development Group, San Diego, California; Chief of Naval Operations, Navy Department, Washington, D.C.; Naval Education and Training Support Center Pacific, San Diego, California; and Chief of Naval Technical Training, Millington, Tennessee.

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THE UNITED STATES NAVY

GUARDIAN OF OUR COUNTRY

The United States Navy is responsible for maintaining control of the sea and is a ready force on watch at home and overseas, capable of strong action to preserve the peace or of instant offensive action to win in war.

It is upon the maintenance of this control that our country's glorious future depends; the United States Navy exists to make it so.

WE SERVE WITH HONOR

Tradition, valor, and victory are the Navy's heritage from the past. To these may be added dedication, discipline, and vigilance as the watchwords of the present and the future.

At home or on distant stations we serve with pride, confident in the respect of our country, our shipmates, and our families.

Our responsibilities sober us; our adversities strengthen us.

Service to God and Country is our special privilege. We serve with honor.

THE FUTURE OF THE NAVY

The Navy will always employ new weapons, new techniques, and greater power to protect and defend the United States on the sea, under the sea, and in the air.

Now and in the future, control of the sea gives the United States her greatest advantage for the maintenance of peace and for victory in war.

Mobility, surprise, dispersal, and offensive power are the keynotes of the new Navy. The roots of the Navy lie in a strong belief in the future, in continued dedication to our tasks, and in reflection on our heritage from the past.

Never have our opportunities and our responsibilities been greater.

CONTENTS

CHAPTER 1

RATING INFORMATION AND ADMINISTRATION

This training manual is designed to help you increase your knowledge in the various aspects of the Gas Turbine rating, and to help you prepare for advancement to third and second class petty officer. Your contribution to the Navy depends on your willingness and ability to accept increasing responsibilities as you advance in rate. When you assume the duties of a Gas Turbine System Technician (GS), you begin to accept certain responsibilities for the work of others. As you advance in your career, you accept additional responsibilities in military subjects as well as occupational and training requirements for the GS rating.

FORMATION OF THE GS RATING

In late 1975 with the commissioning of the USS *Spruance* (DD-963), the Navy realized there was a need for the formation of a specialized Gas Turbine rating. At that time, personnel drawn primarily from the Engineman (EN), Electrician's Mate (EM), and Interior Communications Electrician (IC) ratings were being put through special gas turbine pipeline training for duty aboard the new gas turbine ships. Then, in 1978 the decision was made to form the Gas Turbine System Technician (Electrical) (GSE) and Gas Turbine System Technician (Mechanical) (GSM) ratings. On October 1, 1978 both ratings were put into effect. All ENs, EMs, and ICs with DD-963 class Naval Enlisted Classification Codes (NECs) were automatically converted to GSM or GSE as applicable. Then, with the introduction of the *Oliver Hazard Perry* (FFG-7) to the fleet, more schools and NECs were required to properly train personnel to maintain and operate these ships.

DUTIES AND RESPONSIBILITIES

As a third or second class GS, you have the opportunity to work with a wide variety of main propulsion, auxiliary, and electrical equipments.

The GSM is primarily responsible for the operation and maintenance of the gas turbine modules (GTMs), gas turbine generators (GTGs), reduction gears, and associated equipment such as pumps, valves, oil purifiers, heat exchangers, shafts, and shaft bearings.

The GSE is primarily responsible for the electronic control circuitry, interfaces such as signal conditioners, control consoles, and designated electrical equipment associated with shipboard propulsion, and electrical power generating plants.

As you continue to advance in the Navy, you will increasingly cross train between GSM and GSE to prepare you for more demanding assignments.

This manual is organized to give you a systematic understanding of your job. The occupational standards used in preparing the text are contained in the *Manual of Navy Enlisted Manpower and Personnel Classifications and Occupational Standards*, NAVPERS 18068-D. We recommend that you study the GSM and GSE sections of NAVPERS 18068-D to gain an understanding of the skills required of a GS. Then study the subject matter carefully. The knowledge you gain will enable you to become a more proficient technician, and the Navy profits from your skills.

Further technical training on the DD-963, CG-47, or the FFG-7 platforms is gained

through the appropriate class "C" schools. Successful completion of these "C" schools awards an NEC.

As you advance to third and then to second class petty officer, your responsibilities for military leadership will be about the same as those of petty officers in other ratings. (All petty officers have military as well as technical duties.) Your responsibilities for technical leadership are special to your rating and directly related to your work as a GS. Operating and maintaining a ship's engineering plant and associated equipment requires teamwork along with a special kind of leadership ability that can be developed only by personnel who have a high degree of technical competence and a deep sense of personal responsibility. Strive to improve your leadership ability and technical knowledge through study, observation, and practical application.

Technical leadership involves more than just giving orders. In fact, you can demonstrate some of the most important aspects of technical leadership even if you are not directly supervising other personnel. As a GS, you demonstrate technical leadership when you follow orders exactly, when you follow safety precautions, and when you accept responsibility. Also, when you continue to increase your professional knowledge and when you perform every detail of your work with integrity and reliability, you improve your technical leadership know-how.

Another way in which to gain additional leadership skills is through attendance at the Leadership, Management, and Education Training school (LMET). All petty officers should attend this school to fine tune the leadership skills they have attained through study, observation, and application.

At various times throughout your Navy career, you may also attend various fire-fighting and damage control schools. There can NEVER be enough emphasis placed on the importance of damage control aboard ship. You will find that damage control and fire drills are held routinely in port, at sea, and during special fleet exercises or refresher training. You must learn your duties for damage control emergencies to the very best of your ability because your life and the lives of your shipmates may depend on your actions.

ENGINEERING OPERATIONAL SEQUENCING SYSTEM (EOSS)

The purpose of EOSS is to detail the sequential operational functions for the complete cycle of plant evolutions. Each plant evolution becomes a plant procedure, which is supplied to the engineering officer of the watch. The use of correct operating and casualty control techniques should reduce casualties resulting from personnel error and increase equipment use and life.

If the EOSS is followed, all watch standing will be improved and standardized. Watch standers will develop and maintain maximum proficiency in engineering operation and casualty control procedures. These improvements will contribute to the operational readiness of the engineering department.

EOSS has a secondary feature in that it is an excellent aid for indoctrinating and training newly assigned engineering personnel, providing training for advancement in rating, and preparing for refresher training. This training, in turn, also helps to assure the overall operational readiness of the engineering department.

EOSS is broken down into two subdivisions: Engineering Operational Procedures (EOP) and Engineering Operational Casualty Control (EOCC).

Since EOSS is tailored for each particular ship, complete details are not given in this training manual. For complete information, study the EOSS provided for your ship. It is a ready reference.

PERSONNEL QUALIFICATION STANDARDS (PQS)

PQS documents describe the knowledge and skills a trainee must have to perform certain duties. They speed up the learning progress since each person knows exactly what information to obtain to prepare for qualifying in increasingly complex duties. They individualize learning so each person may take advantage of opportunities to learn on the job. They place the responsibilities for learning on the trainee and encourage self-achievement. By providing a convenient record of accomplishment, they offer a means whereby

supervisors can check individual speed and performance.

Since the PQS has been assembled by groups of experienced officers and petty officers, they attempt to represent the guidance that would be furnished if each person had an individual instructor throughout each step.

PQS is designed to support advancement in rating requirements as stated in the *Navy Enlisted Manpower and Personnel Classifications and Occupational Standards*, NAVPERS 18068-D.

Every PQS contains the following sections:

1. Introduction
2. Glossary of Qualification Standard Terms
3. Table of Contents
4. 100 series—Theory
5. 200 series—Systems
6. 300 series—Watch Standing
7. 400 series—Qualification Cards
8. Bibliography
9. Feedback Forms

RATE TRAINING MANUALS

There are two general types of rate training manuals (RTMs). RATING manuals (such as this one) are prepared for most enlisted ratings. A rating manual gives information directly related to the occupational standards on one rating. SUBJECT MATTER manuals or BASIC manuals give information that applies to more than one rating.

RTMs are revised from time to time to keep them up-to-date technically. The revision of a rate training manual is identified by a letter following the NAVEDTRA number. You can tell whether any particular copy of a training manual is the latest edition by checking the NAVEDTRA number and the letter following this number in the most recent edition of *List of Training Manuals and Correspondence Courses*, NAVEDTRA 10061. (NAVEDTRA 10061 is actually a catalog that lists all current training manuals and courses; you will find this catalog useful in planning your study program.)

Each time an RTM is revised, it is brought into conformance with the official publications and directives on which it is based. However, during the life of any edition of an RTM, changes are made to the official sources and discrepancies arise. In the performance of your duties, you should always refer to the appropriate official publication or directive. If the official source is listed in *Bibliography for Advancement Examination Study*, NAVEDTRA 10052, the Naval Education and Training Program Development Center uses it as a source of questions in preparing the fleetwide examinations for advancement. In case of discrepancy between any publications listed in NAVEDTRA 10052 for a given rate, the examination writers use the most recent material.

RTMs are designed to help you prepare for advancement. The following suggestions may help you to make the best use of this manual and other Navy training publications when you prepare for advancement.

1. Study the naval standards and the occupational standards for your rating before you study the training manual and refer to the standards frequently as you study. Remember, you are studying the manual primarily to meet these standards.

2. Set up a regular study plan. It will probably be easier for you to stick to a schedule if you can plan to study at the same time each day. If possible, schedule your studying for a time of day when you do not have many interruptions or distractions.

3. Before you begin to study any part of the manual intensively, become familiar with the entire book. Read the preface and the table of contents. Check through the index. Thumb through the book without any particular plan. Look at the illustrations and read bits here and there as you see things that interest you. Review the glossary. It provides definitions that apply to words or terms as they are used within the engineering field and within the text. There are many words with more than one meaning. Do not

assume that you know the meaning of a word! As you study, if you cannot recall the use of a word, look it up in the glossary. For your convenience, a list of abbreviations and a table on conversion to the metric system appear as appendixes in the back of this manual.

4. Look at the training manual in more detail to see how it is organized. Look at the table of contents again. Then, chapter by chapter, read the introduction, the headings, and the subheadings. In this manner you will get a pretty clear picture of the scope and content of the book. As you look through the book, ask yourself some questions.

- What do I need to learn about this?
- What do I already know about this?
- How is this information related to information given in other chapters?
- How is this information related to the occupational standards?

EDUCATIONAL GUIDANCE

There are numerous personnel aboard ship who can assist you in furthering your Navy education. Your division training petty officer can help you with any questions you may have about where to obtain study material. He is also the person who generally issues you your PQS material and maintains the associated progress chart.

The educational services officer (ESO) maintains the RTMs, nonresident career courses (NRCCs), if published separately from the RTMs, and NRCC answer sheets. The ESO can also assist you with off-duty education such as the Scholastic Aptitude Test (SAT) and College Level Examination Program (CLEP) tests, as well as enrollment in local colleges.

The command career counselor can assist you in applying for schools, arranging for duty stations in conjunction with GUARD reenlistments, and any other questions you may have about your career path.

SOURCES OF INFORMATION

One of the most useful things you can learn about a subject is how to find out more about it. No single publication can give you all the information you need to perform the duties of your rating. You should learn where to look for accurate, authoritative, up-to-date information on all subjects related to the naval requirements for advancement and the occupational standards of your rating.

In this section we shall discuss most of the publications you will use. The detailed information you need for advancement and for everyday work is contained in them. Some are subject to change or revision from time to time—some at regular intervals, others as the need arises. When using any publication that is subject to change or revision, be sure you have the latest edition. When using any publication that is kept current by means of changes, be sure you have a copy in which all official changes have been made. Studying canceled or obsolete information does not help you to do your work or to advance in rate. At best, it is a waste of time; at worst, it is likely to be dangerously misleading.

The publications issued by the Naval Sea Systems Command (NAVSEA) are of particular importance to engineering department personnel. Although you do not need to know everything in these publications, you should have a general idea of where to find the information contained therein.

NAVAL SHIPS' TECHNICAL MANUAL

The *Naval Ships' Technical Manual* (NSTM) is the basic engineering doctrine publication of NAVSEA. The manual is kept up-to-date by means of quarterly changes. As new chapters are issued, they are being designated by a new chapter numbering system.

The following chapters of the *Naval Ships' Technical Manual* are of particular importance

to GSs; both the new and old number for each chapter are listed.

NEW	OLD	CHAPTER
078	(9950)	Gaskets, Packings, and Seals
220 Vol. 2	(9560)	Boiler Water/Feed Water Chemistry Test and Treatment
221		Boilers
234	(9416)	Marine Gas Turbines
	(9540)	Gas Turbines
241	(9420)	Reduction Gears
243	(9430)	Shafting
244	(9431)	Bearings
245	(9440)	Propellers
254	(9460)	Condensers and Heat Exchangers
255	(9562)	Feed Water Systems
262	(9450)	Lubricating Oils and Greases
300	(9600)	Electric Plants
302	(9630)	Electric Motors and Controllers
491	(9690)	Electrical Measuring and Test Equipment
503	(9470)	Pumps
504	(9870)	Pressure and Temperature Measuring Devices
505	(9480)	Piping Systems
541	(9550)	Petroleum Fuel Stowage, Use

MANUFACTURERS' TECHNICAL MANUALS

Another important source of information you can use is the manufacturer's technical manual for the piece of equipment you are working on. These manuals contain all the information necessary for troubleshooting, overhaul, and repair. In the case of the gas turbine engines, they contain information on component change-out and engine change-out.

DRAWINGS

Some of your work as a GS requires an ability to read and work from mechanical drawings. You can find information on how to read and interpret drawings in *Blueprint Reading and Sketching*, NAVEDTRA 10077 (with changes).

In addition to knowing how to read drawings, you must know how to locate applicable drawings. For some purposes, the drawings included in the manufacturers' technical manuals for the machinery or equipment may give you the information you need. In many cases, however, you may find it necessary to consult the onboard drawings. The onboard drawings, which are sometimes referred to as ship's plans or ship's blueprints, are listed in an index called the ship drawing index (SDI). The SDI lists all working drawings that have a NAVSHIPS drawing number, all manufacturers' drawings designated as certification data sheets, equipment drawing lists, and assembly drawings that list detail drawings. The onboard drawings are identified in the SDI by an asterisk (*).

Drawings are listed in numerical order in the SDI. Onboard drawings are filed according to numerical sequence. There are two types of numbering systems in use for drawings that have NAVSHIPS numbers. The older system is an S-group numbering system. The newer system, used on all NAVSHIPS drawings since 1 January 1967, is a consolidated index numbering system. A cross-reference list of S-group numbers and consolidated index numbers is given in *NAVSHIPS Consolidated Index of Materials and Services Related to Construction and Conversion*.

SHIPS' MAINTENANCE AND MATERIAL MANAGEMENT SYSTEM (3-M)

The primary objective of the 3-M Systems is to provide for managing maintenance and maintenance support in a way to ensure maximum operational readiness. The 3-M Systems has three separate subsystems. They are the Planned Maintenance System (PMS), the Maintenance Data System (MDS), and the Intermediate Maintenance Activity Maintenance Management System (IMMS). Of these three, we will deal primarily with PMS and MDS in this chapter.

PURPOSES OF PMS

The PMS was established for several purposes:

1. To reduce complex maintenance to simplified procedures that are easily identified and managed at all levels
2. To define the minimum planned maintenance required to schedule and control PMS performances
3. To describe the methods and tools to be used
4. To provide for the detection and prevention of impending casualties
5. To forecast and plan manpower and material requirements
6. To plan and schedule maintenance tasks
7. To estimate and evaluate material readiness
8. To detect areas requiring additional or improved personnel training and/or improved maintenance techniques or attention
9. To provide increased readiness of the ship

BENEFITS OF PMS

PMS is a tool of command. By using PMS, the commanding officer can readily determine whether his ship is being properly maintained. Reliability is intensified. Preventive maintenance reduces the need for major corrective maintenance, increases economy, and saves the cost of repairs.

PMS assures better records, since it has more data that can be useful to the shipboard maintenance manager. The flexibility of the system allows for programming of inevitable changes in employment schedules. This helps to better plan preventive maintenance.

Better leadership and management can be realized by reducing frustrating breakdowns and irregular hours of work. PMS offers a means of improving morale and thus enhances the effectiveness of all hands.

LIMITATIONS OF PMS

The PMS is not self-starting; it does not automatically produce good results; considerable professional guidance is required. Continuous direction at each level must be maintained. One individual must be assigned both the authority and the responsibility at each level of the system's operation.

Training in the maintenance steps as well as in the system is necessary. No system is a substitute for the actual, technical ability required of the petty officers who direct and perform the upkeep of the equipment.

CURRENT SHIPS MAINTENANCE PROJECT (CSMP)

The CSMP is a numerical listing of outstanding deficiencies for all work centers aboard ship. Previously, the CSMP was prepared and distributed by an appropriate shore facility. However, because of deployment schedules and delays in mailing, it did not reflect the actual status of completed actions. Now, with the introduction of a 3-M computer system, most ships can prepare and update their own CSMP and deliver it on tape to the appropriate shore facility.

As a third or second class petty officer, you are required to learn to prepare OPNAV 4790/2K forms for deferred actions and/or work requests. If a problem arises with a piece of equipment that cannot be repaired within 30 days, you must prepare a deferred action. If the problem is beyond a ship's force capabilities to repair, you have to prepare a deferred action/work request. It is very important that you maintain a timely and accurate account for trend analysis so supervisors can organize effective work schedules.

Because of rapid changes in the 3-M Systems, you should refer to a current copy of the *Ships' Maintenance and Material Management (3-M) Manual*, OPNAV 4790.4, Volumes 1, 2, and 3, for more information.

MEASURE PROGRAM

The Metrology Automated System for Uniform Recall and Reporting (MEASURE) is designed to provide a standardized system for recall and calibration of selected gauges, instruments, and test equipment. To ensure that all equipment requiring calibration is maintained at maximum dependability, the scheduling and reporting of data is automated.

After an initial inventory of equipment is completed, on preprinted METER cards, a recall

schedule is set up for the reporting activity. The information is processed and calibration scheduling is furnished to the reporting activity on a monthly basis. When the calibration facility performs the required service, they complete the METER card. As the METER cards are processed, the data base is updated and the system continues to cycle.

GAS TURBINE RECORDS AND ENGINEERING ADMINISTRATION

The Engineering Log and the Engineer's Bell Book or Automatic Bell Log are the only legal records compiled by the engineering department. The Engineering Log is a midnight-to-midnight record of the ship's engineering department. The Engineer's Bell Book or Automatic Bell Log is a legal record of any order regarding a change in the movement of the propellers.

ENGINEERING LOG

The Engineering Log, NAVSEA 3120/2B (figure 1-1), and the Engineering Log-Continuation, NAVSEA 3120/2C (figure 1-2), are used to record important daily events and data pertaining to the engineering department and the operation of the engineering plant. Spaces are provided for recording equipment in operation; ship's draft and displacement; liquid load in gallons and percent; the name of the ship, the date, and the location or route of the ship, and remarks chronicling important events.

Entries in the Engineering Log must be made following instructions given (1) on the Engineering Log-Instructions, NAVSEA 3120/2D (figure 1-3), (2) in chapter 10 of *U.S. Navy Regulations*, (3) in chapter 090 (9004) of *Naval Ships' Technical Manual*, and (4) in directives from the type commander.

Remarks written in the Engineering Log must include (1) personnel casualties (injuries), (2) equipment casualties, (3) changes in equipment status, (4) changing to or from maneuvering combinations, and (5) such other matters as specified by competent authority. Each entry must be written at the time the event occurred. It must be a complete statement using standard phraseology. Type commanders may increase the recording requirements. An instruction may be published including any such additional requirements.

The original Engineering Log, prepared neatly in ink or pencil, is the legal record. The remarks should be prepared and must be signed by the engineering officer of the watch (EOOW) (under way) or the engineering duty officer (EDO) (in port). No erasures are permitted in the log. When a correction must be made, a single line is drawn through the original entry so that it remains legible. Then the correct entry is written in. Corrections, additions, or changes can only be made by the person required to sign the log for that watch, and that person must initial the margin of the page.

The engineer officer reviews the log daily for completeness and accuracy and signs it in the space provided. The commanding officer approves and signs the Engineering Log-Title Page, NAVSEA 3120/2A (figure 1-4), on the last calendar day of each month and on the day he relinquishes command.

Completed Engineering Log sheets are filed in a ring or post binder and retained on board for 3 years. Pages of the log are numbered consecutively with a new series of page numbers commencing on the first day of each month.

ENGINEER'S BELL BOOK

The Engineer's Bell Book, NAVSHIPS 3120/1, shown in figure 1-5, is a record of all orders received by the station in control of the throttles regarding a change in the movement of the propellers. Entries are made by the throttle operator (or assistant) as soon as an order is received. Entries may be made by an assistant when the ship is in a special maneuvering situation that may call for numerous or rapid speed changes. This allows the throttle operator to give complete attention to answering the bells.

The Engineer's Bell Book is maintained in the following manner:

1. A separate bell sheet is used for each shaft each day, except when more than one shaft is controlled by the same station. In this case, the same sheet is used for all shafts controlled by that station.

2. The time the order was received is recorded in column 1 (figure 1-5).

ENGINEERING LOG
NAVSEA 3120/2B (REV. 10-81) S/N 0116-LF-031-2115 (9-77 EDITION IS OBSOLETE) CLASSIFICATION

U.S.S. | HULL NUMBER

DAY	MONTH	YEAR	TIME ZONE	TIME ZONE CHANGE TO	TIME ZONE CHANGE FROM

AT/PASSAGE FROM | PASSAGE TO | TOTAL MILES TRAVELED TODAY

EQUIPMENT STATUS *(Need not be completed for continuing pages)*

MAIN ENGINES | PLANT STATUS | BOILERS

GENERATORS | STEERING ENGINES COMBINATION

DAYS OUT OF DRY DOCK | CATAPULT STATUS *(CV's Only)* | DAYS SINCE LAST HULL CLEANING

DRAFT FWD | DRAFT AFT | DRAFT MEAN | TONS

LIQUID LOAD | PERCENT OF FULL LOAD (%)

MAJOR EQUIPMENT OUT OF COMMISSION

EXAMINED DAILY AND CERTIFIED TO BE CORRECT

SIGNATURE OF ENGINEER OFFICER/RANK | DATE OF SIGNATURE

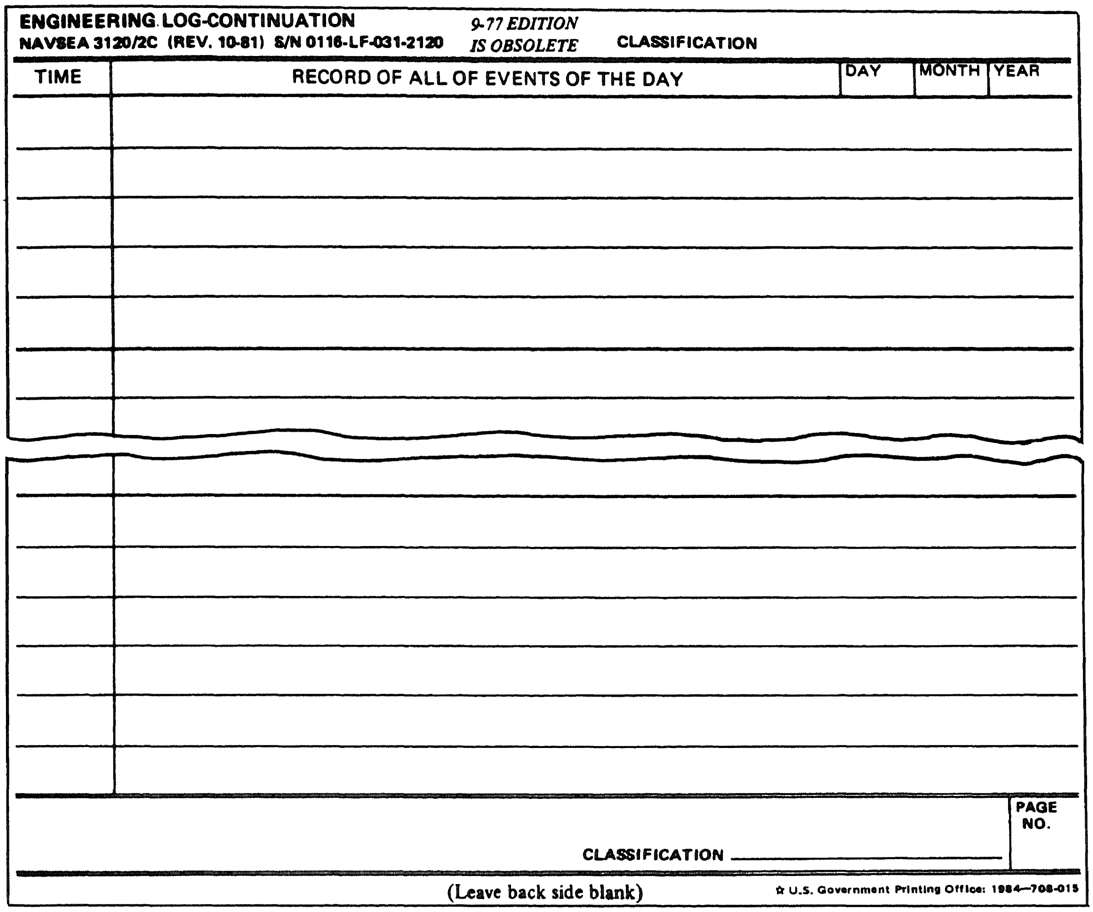
TIME	RECORD OF ALL EVENTS OF THE DAY	DAY	MONTH	YEAR

CLASSIFICATION | PAGE NO.

(Leave back side blank)

291.1

Figure 1-1.—Engineering log, NAVSEA 3120/2B.


ENGINEERING LOG-CONTINUATION 9-77 EDITION IS OBSOLETE
NAVSEA 3120/2C (REV. 10-81) S/N 0116-LF-031-2120 CLASSIFICATION

TIME	RECORD OF ALL OF EVENTS OF THE DAY	DAY	MONTH	YEAR

PAGE NO.
CLASSIFICATION
(Leave back side blank) ☆ U.S. Government Printing Office: 1984—708-015

291.2

Figure 1-2.—Engineering log continuation sheet, NAVSEA 3120/2C.

3. The order received is recorded in column 2. Minor speed changes are recorded by entering the RPM or pitch change ordered. Major speed changes are recorded using the following symbols:

1/3—ahead 1/3 speed
2/3—ahead 2/3 speed
I—ahead standard speed
II—ahead full speed
III—ahead flank speed
Z—stop
B1/3—back 1/3 speed
B2/3—back 2/3 speed
BF—back full speed
BEM—back emergency speed

4. The RPM corresponding to the major speed change ordered is entered in column 3. When the order is a minor speed change of RPM only, no entry is made in column 2.

5. The pitch set is recorded in feet (FFG-7 class) or percent (DD-963/DDG-993/CG-47 classes) in column 4.

Before going off watch, the throttle operator and the EOOW sign the log on the two lines following the last entry. The next watch continues the record immediately thereafter.

When control is at the ship control console (SCC) on the bridge, the Engineer's Bell Book is maintained by bridge personnel. When control is shifted to the central control station (CCS), the

ENGINEERING LOG-INSTRUCTIONS
NAVSEA 3120/2D (REV. 10-81) S/N 0116-LF-031-2125

9-77 EDITION IS OBSOLETE

FOR OFFICIAL USE ONLY

ENGINEERING LOG INSTRUCTIONS FOR ALL SURFACE SHIPS

Instructions For Keeping The Engineering Log - Title Page, Form NAVSEA 3120/2A (Rev. 10-81); Engineering Log, Form NAVSEA 3120/2B (Rev. 10-81); Engineering Log - Continuation, Form NAVSEA 3120/2C (Rev. 10-81); Engineering Log - Instructions, Form NAVSEA 3120/2D (Rev. 10-81)

(For All Surface Ships)

1. The Engineering Log shall be maintained in accordance with Art. 0724 of Navy Regulations, and Section 423 of OPNAVINST 3120.32A. It shall be neatly written in pen or pencil. The original writing is the legal record and must be preserved. It is not desired that the log be recopied except when one or more pages are sent away from the ship. A reproduced copy will then be used.

2. If the information in the sheet is classified, fill in the classification of the log sheet at the top and bottom in the spaces provided. (For example: Classified by: OPNAVINST 3063, Review By: 1 Mar 1992).

3. Fill out the data cover sheet, form NAVSEA 3120/2A.

a. Page numbering shall be completed with the number on the last page of the last day of the month.

b. Examined and approved signatures are completed at the end of the month.

4. Complete the log. All unused blanks shall be crossed out. Do not erase. All errors shall be lined out, initialed, and dated by the person making the original entry.

a. Fill in the heading. Fill in the total miles traveled at the end of the day.

b. Fill in the equipment status section. This section must be completed on the first page of each day only. Continuation sheets will be used when required.

(1) Main engines - Enter engines which are in use. (If a single engine ship, enter number one.)

(2) Plant status - Enter split/cross-connected/cold iron/auxiliary/modified main, etc.

(3) Boilers - Enter boilers which are on the line.

(4) Generators - Enter SSTG/SSDG which are on the line and in parallel operation, e.g., 1 and 2, 4 and 6, --- , ---- .

(5) Steering engines combination - Enter both unit (motor) and cable.

(6) Enter the number of days out of dry dock.

(7) Enter catapults which are operating and from which spaces each is being provided with steam, e.g., 1/2, 2/4, 3/2, 4/3.

(8) Enter the number of days since the last hull cleaning.

(9) Enter the draft readings when in port. When underway, enter the percentage of liquid load (in gallons), fuel (including aircraft if applicable) and water (including ballast and list control if applicable). Then, calculate the draft from the percent of full load, which shall include ammunition and food.

(10) Major equipment out of commision (OOC)- Enter engines, boilers, SSTG/SSDG, emergency generators, steering gear and combinations of major auxiliary equipment which cause main machinery to be OOC, e.g., # 1A and B lube oil service pumps, or # 2A and B FDB, etc. The intent of this section is to list only those components which affect the overall operation of the ship by placing a limitation on the performance or flexibility of the ship. If space is not sufficient to make all entries, they shall be continued in the section "RECORD OF EVENTS OF THE DAY"

c. Examined daily and certified to be correct: This section shall be examined, verified as correct and signed by the Engineering Officer at the end of each day.

d. Page numbers-Pages shall be numbered consecutively with the first day of each month numbered page one. The back of each page shall be left blank.

e. Record the events of the day.

(1) Remarks shall be entered by watch or days as applicable.

(2) The remarks shall be a chronological listing of the day's events, each of which shall be written at the time of occurrence. The following is a complete listing of all requirements generated by the chain of command above the Type Commander level. If Type Commanders desire to increase the recording requirements, an instruction shall be published in the 3100 series including all additional requirements

(a) Personal casualties

(b) Equipment casualties

(c) Shifting of major equipment

(d) Changing to and from maneuvering combinations

(e) Beginning and ending major evolutions-General Quarters, refueling, entering port, etc.

(f) Change in catapult status (CV only)

(g) Shifting lube oil strainers

(h) Opening and inspecting main engines, generators and boilers, and any changes made therein

(i) Setting safeties on boilers

(j) Disposition and changes in principal auxiliaries which affect main machinery operation

5. The Engineering Log may be destroyed 3 years after the date of the last entry. When a ship is stricken, current logs must be forwarded to the nearest Records Management Center

FOR OFFICIAL USE ONLY

Figure 1-3.—Engineering log instructions, NAVSEA 3120/2D. 291.3

ENGINEERING LOG-TITLE PAGE
NAVSEA 3120/2A (REV. 10-81) S/N 0116-LF-031-2110 *NAVSEA 3120/2 (9-77) IS OBSOLETE* FOR OFFICIAL USE ONLY

ENGINEERING LOG

U.S.S. ________________

HULL NUMBER ________________

FOR MONTH OF: ________________

FOR YEAR OF: ________________

CONSISTING OF PAGES 1 THROUGH ____

EXAMINED DAILY AND CERTIFIED TO BE CORRECT:

SIGNATURE OF ENGINEER OFFICER/RANK	DATE OF CERTIFICATION

APPROVED BY:

SIGNATURE OF COMMANDING OFFICER/RANK	DATE APPROVED

FOR COMPLETION UPON CHANGE OF COMMAND

SIGNATURE OF COMMANDING OFFICER BEING RELIEVED/RANK	DATE OF CHANGE OF COMMAND

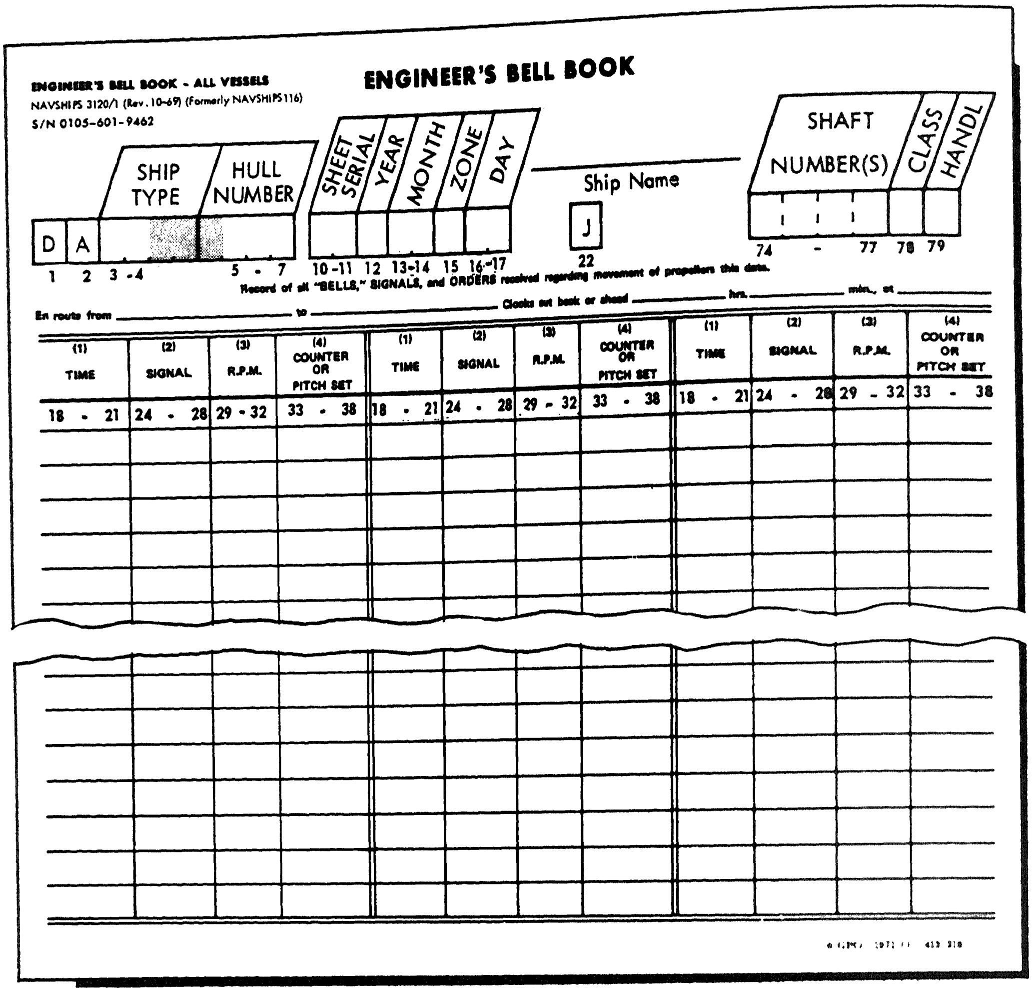
PRINTED NAME OF COMMANDING OFFICER BEING RELIEVED

TO BE RETAINED ON BOARD 3 YEARS

FOR OFFICIAL USE ONLY

291.4

Figure 1-4.—Engineering log title page, NAVSEA 3120/2A.


ENGINEER'S BELL BOOK - ALL VESSELS
NAVSHIPS 3120/1 (Rev. 10-69) (Formerly NAVSHIPS 116)
S/N 0105-601-9462

ENGINEER'S BELL BOOK

D	A	SHIP TYPE	HULL NUMBER	SHEET SERIAL	YEAR	MONTH	ZONE	DAY	Ship Name	SHAFT NUMBER(S)	CLASS	HANDL
1	2	3 - 4	5 - 7	10 - 11	12	13 - 14	15	16 - 17	J 22	74 - 77	78	79

Record of all "BELLS," SIGNALS, and ORDERS received regarding movement of propellers this date.

En route from ______ to ______ Clocks set back or ahead ______ hrs. ______ min., at ______

(1) TIME	(2) SIGNAL	(3) R.P.M.	(4) COUNTER OR PITCH SET	(1) TIME	(2) SIGNAL	(3) R.P.M.	(4) COUNTER OR PITCH SET	(1) TIME	(2) SIGNAL	(3) R.P.M.	(4) COUNTER OR PITCH SET
18 - 21	24 - 28	29 - 32	33 - 38	18 - 21	24 - 28	29 - 32	33 - 38	18 - 21	24 - 28	29 - 32	33 - 38

77.23

Figure 1-5.—Engineer's bell book, NAVSHIPS 3120/1.

Engineer's Bell Book is maintained by CCS personnel. If throttles must be maintained in the engine room, those personnel would keep the record.

Alterations or erasures are not permitted in the Engineer's Bell Book. Incorrect entries are corrected in the same manner as the Engineering Log by drawing a single line through the incorrect entry and recording the correct entry on the following line. Deleted entries are initialed by the EOOW, OOD, or watch supervisor as appropriate.

On DD-963, DDG-993, and CG-47 class ships, the automatic bell logger is also a legal record. The automatic printouts are signed by th EOOW at the end of each watch in the sam manner as the Engineer's Bell Book. When th bell logger and/or the data printer are in opera tion, all bells are automatically logged. It is no necessary to maintain a bell book unless specifie by local instructions.

BELL AND DATA LOGGERS

With all the equipment that must b monitored and all the information that must b logged for future reference, it is almo impossible for an operator to operate th console and write a log. For this reason, two lir

printers (figure 1-6) receive information from a computer or processor and log this information automatically. These line printers are the bell logger and the data logger.

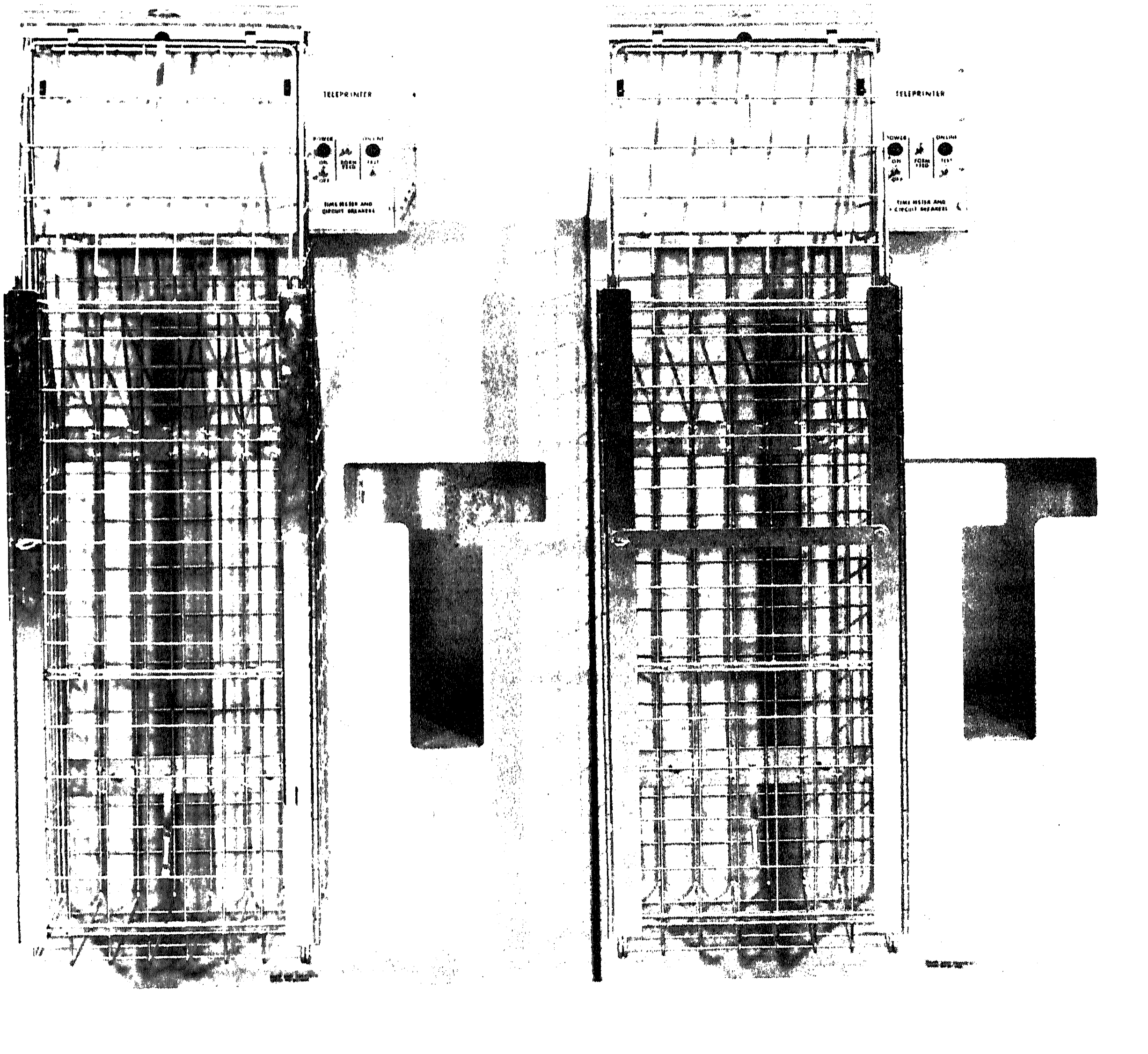
Bell Logger

The bell logger prints only bell signals and replies to those signals; all other logging functions are done by the data logger.

Data Logger

The data logger is responsible for all logging functions not performed by the bell logger—data logging, alarm logging, status change logging, trend logging, and demand print logging. These five functions are described below.

DATA LOG.—The data logging function provides a record of the values and/or status of all parameters of interest, either automatically at



286.51

Figure 1-6.—Line printers.

selected time intervals or upon operator demand (DD-963/DDG-993/CG-47 classes only).

ALARM LOG.—The alarm logging function provides a permanent record of all changes in alarm conditions as they occur, including both the alarm itself and its acknowledgement or reset.

CHANGE OF STATUS LOG.—The change of status logging function records nonalarming changes in the discrete status of certain parameters such as pump on/off or pump fast/slow.

TREND LOG.—The trend logging function provides continuous and automatic monitoring of up to 16 operator-selected parameters and automatic printout if a parameter's value changes by more than a preset threshold (percentage).

The demand print functions are just what the name implies. When the operator wants a printout of an individual item or a group of items, he dials up the address for what is desired to be printed. Then the operator presses the print button.

If either of the line printers should fail to operate properly, the remaining operable printer automatically assumes all logging duties. In this event, the priorities for logging time in order of highest priority to lowest are as follows:

1. Bell logging
2. Alarm logging
3. Status change logging
4. Trend logging
5. Demand and data logging

EQUIPMENT OPERATING LOGS

Equipment monitors are required to maintain a variety of handwritten machinery logs. These are prepared by each command and cover equipment designated by the type commanders, squadron commanders, and your own command. Items generally covered include waste heat boilers, GTGs, air compressors, reduction gears, and line shaft bearings. This is by no means a complete list of logs that may be maintained, as each command has different requirements.

All equipment operating logs are prepared with high- and low-limit set points printed for each reading. All "out of limits" readings must be circled in red. The reason for the "out of limits" condition and the action taken to correct the condition must be noted in the Remarks section of the log. At the end of each watch, the EOOW should review and initial all of the logs for his watch.

OPERATING ORDERS

The various operating orders that you must become familiar with include standard (or standing) orders, standing orders for special evolutions, and night orders.

The commanding officer's standing order pertaining to the engineering department is the Restricted Maneuvering Doctrine. This is an instruction that is reviewed by each new commanding officer and approved or revised to his own requirements. It includes main engine combinations, generator combinations, standby setups, and casualty procedures to use during maneuvering in restricted waters or alongside another ship. The commanding officer's Restricted Maneuvering Doctrine may also include instructions on casualty control procedures during general quarters.

The engineer officer also has standing orders covering a wide variety of subjects. They include instructions for watch standers, reporting procedures for casualties, and log entries to be made.

Another standing order, which is more of a shipboard instruction, is the ship's Fire Doctrine. All personnel aboard ship need to familiarize themselves with its contents. The Fire Doctrine contains all the information necessary to know for reporting, fighting, and extinguishing a shipboard fire.

Night orders are written by the engineer officer while under way. They include any special instructions the engineer officer may have for the watch standers. They are usually written and delivered to CCS on the 2000 to 2400 watch. These orders have information on all propulsion and auxiliary equipment in use, any expected major speed changes, or changes to plant status.

GAS TURBINE ENGINEERING SAFETY

To ensure safety, operating personnel must be thoroughly familiar with the technical manuals and other publications concerning equipment under their care. Operating personnel must continuously exercise good judgment and employ common sense in the preparation, setting-up, and operation of all engines to prevent damage to the engines and injury to personnel. Good judgment is of the utmost importance when considering safety.

Damage to machinery may be prevented by proper preparation and operation of engines by following instructions and procedures outlined in EOSS; by cleanliness in handling all parts of the engine, lubricating oils, and fuel oils; by a thorough knowledge of duties; and by a complete familiarity with all parts and functions of the machinery.

Damage to the ship may be prevented by handling the machinery so there is no loss of power at an inopportune time, by keeping engines ready for service in any emergency, and by preventing conditions likely to cause fire or explosion hazards.

Injury to personnel may be prevented by a thorough knowledge of duties, by proper handling of tools and parts, by normal precautions around moving parts, by adequate guards at constantly exposed danger points, and by constant training to eliminate carelessness and thoughtlessness.

Maintain clean fuel, air, coolants, lubricants and operating spaces. Prevent the accumulation of oil in the bilges or other pockets or foundations and subbases. Take care, particularly when on an uneven keel, that water in the bilges does not reach electrical machinery or wiring.

Ensure that safety guards are provided at exposed danger points. Emphasize the proper handling of tools and parts.

Maintain fire-fighting equipment in good order and readiness at all times in case of engine-room fire.

SPECIFIC SAFETY PRECAUTIONS

In the interest of personnel and machinery safety, adhere to the following precautions with intense regularity:

1. Do not attempt to operate the engine by wiring around or opening circuits to automatic shutdown or warning devices.
2. Disconnect batteries or other sources of electrical power before performing maintenance. This prevents injuries from short circuits and accidental cranking of engines.
3. Avoid holding or touching spark plugs, ignition units, or high tension leads while energized.
4. Use proper cautions when turning an engine by hand to prevent injuries to fingers or hands.
5. Retain adequate speed control of the power turbine by keeping fuel control and speed control governors connected. Do not, under any circumstances, disconnect governors when operating or starting an engine.
6. Do not use oxygen to pressure test fuel lines and equipment.
7. Do not use compressed air to spin ball or roller bearings after cleaning.
8. Take precautions to avoid inhaling vapors of lacquer thinner, trichlorethylene, and similar solvents.
9. Avoid changes to the high speed stop on the fuel control and adjustments to the speed control governors. If you have to make adjustments, follow the technical manual.
10. Follow the technical manual guide for making periodic inspection and testing of the safety control circuits and automatic shutdown devices.
11. Do not wear jewelry and watches while working on gas turbine engines.
12. Take precautions to avoid touching exposed hot parts of the engine. Do not perform maintenance work until the engine has been shut down and cooled.
13. Assure that all thermal insulation and/or shields are intact and sound as per manufacturer's recommendations to protect against personnel or fire hazards.

14. If a false start is encountered, purge the engine following the EOSS. This is very important and should be emphasized.

15. Take precautions to see that fuel is not allowed in the combustion chamber when there is no flame or igniter spark. Later firing could cause a hot start. Make certain that the combustor drains operate freely.

16. Wear proper ear protection in the engine room while gas turbine engines are in operation.

17. Ensure all ducting permits free flow. Air intake and exhaust openings must allow unrestricted flow of the gas. The performance of gas turbines drops off quite rapidly with increased duct losses.

18. Test overspeed trips and governor mechanisms by following instructions in the technical manuals. Never test the overspeed trip by manually overriding the speed control governor. If the overspeed trip does not function, there is no overspeed protection.

EQUIPMENT TAG-OUT

The purpose of the equipment tag-out program is to provide a procedure to prevent improper operation when a component, equipment, system, or portion of a system is isolated or in an abnormal condition. This procedure should also be used when other safety devices, such as blank flanges, are installed for testing, maintenance, or casualty isolation. Tags applied to valves, switches, or other components should indicate restrictions on operation of systems or equipment, or restrictions necessary to avoid damage to safety devices.

The program also provides a procedure for use when an instrument is unreliable, or is not in normal operating condition. It is similar to the tag-out procedure except that labels instead of tags are used to indicate instrument status.

To standardize tag-out procedures used by ships and repair activities, the procedures in this program are mandatory.

Responsibility

The commanding officer is responsible for the safety of the entire command. It is the duty of the commanding officer to ensure that all personnel know all applicable safety precautions and procedures, and to ensure compliance with the program. The engineer officer is responsible for ensuring that personnel assigned to the engineering department understand and comply with this program.

When repairs are done by a repair activity, a dual responsibility exists for the safety of the repair personnel to ensure that conditions are safe for all work being done. The ship tended is responsible for and controls the tag-out program on the systems that require work. The repair activity is responsible for ensuring compliance with the program.

Information

An effective tag-out program is necessary because of the complexity of modern ships as well as the cost, delay, and hazard to personnel that could result from the improper operation of equipment.

The tag-out program must be enforced at all times. It is necessary during normal operations, as well as during construction, testing, repair, or maintenance. Strict enforcement of tag-out procedures is required by both you and any repair activity that may be working on your equipment.

The use of tags is not a substitute for other safety measures such as locking valves, pulling fuses, or racking out circuit breakers. However, attach tags to the valve, circuit breaker, and so on to indicate the need for the action taken. Never use tags for identification purposes.

Procedures

When you identify the need to tag out a piece of equipment or a system, you must get permission from an authorizing officer. Authorizing officers for the engineering department are usually the EOOW while under way, or the EDO while in port. If the system or equipment tagged is placed out of commission, the authorizing officer must get permission from the engineer officer and the commanding officer. When permission has been received, the authorizing officer then directs you to prepare the tag-out record sheet and tags.

Normally, the petty officer in charge of the work fills out and signs the record sheet and prepares the tags. The record sheet is filled out for a stated purpose. All tags for that purpose are

normally listed on one record sheet. Each sheet is assigned a log serial number. All tags associated with it are given the same log serial number and a sequential number is entered on the record sheet. For example, tag E107-4 is the fourth tag issued on the record sheet with the log serial number 107 for engineering.

The record sheet includes reference to any documents that apply—such as the PMS, technical manuals, and other instructions, the reason for the tag-out, the hazards involved, any amplifying instructions, and the work necessary to clear the tags. Use enough tags to completely isolate the system or circuit being worked on to prevent operation from any and all stations that could exercise control. Indicate the location and condition of the tagged item by the simplest means (for example, FOS-11A, closed).

When the tags and record sheets are filled out, a second person must make an independent check of the tag coverage.

When you attach the tags, you must ensure that the item is in the position or condition indicated on the tag. As you attach each tag, you then must sign the tag and initial the record sheet. After all tags are attached, a second qualified person must independently verify proper tag placement, sign the tags, and initial the record sheet.

Types of Tags

The following is a list of the various tags and the applications required to be used from time to time.

CAUTION TAG.—A YELLOW tag (figure 1-7) is used as a precautionary measure to provide temporary special instructions or to indicate that unusual caution must be exercised to operate equipment. These instructions must give the specific reason that the tag was installed. The use of such phrases as DO NOT OPERATE WITHOUT EOOW PERMISSION is not appropriate since equipment or systems are not operated unless permission has been granted by responsible authority. A CAUTION tag is NOT used any time personnel or equipment can be endangered while performing evolutions using normal operating procedures; a DANGER tag is used in this case.

DANGER TAG.—A RED tag (figure 1-8) is used to prohibit the operation of equipment that could jeopardize the safety of personnel or endanger equipment. Under no circumstances should equipment be operated when tagged with DANGER tags.

OUT-OF-CALIBRATION LABELS.—ORANGE labels (figure 1-9) are used to identify instruments that are out of calibration and may not work properly. This label indicates the instrument may be used for system operation only with extreme caution.

OUT-OF-COMMISSION LABELS.—RED labels (figure 1-10) are used to identify instruments that do not work properly because they are defective or isolated from the system. This indicates the instrument cannot be relied on and must be repaired and recalibrated, or be reconnected to the system before use.

Enforcement

The tag-out log is kept in a designated space, usually CCS. Supervisory watch standers review the log during watch relief.

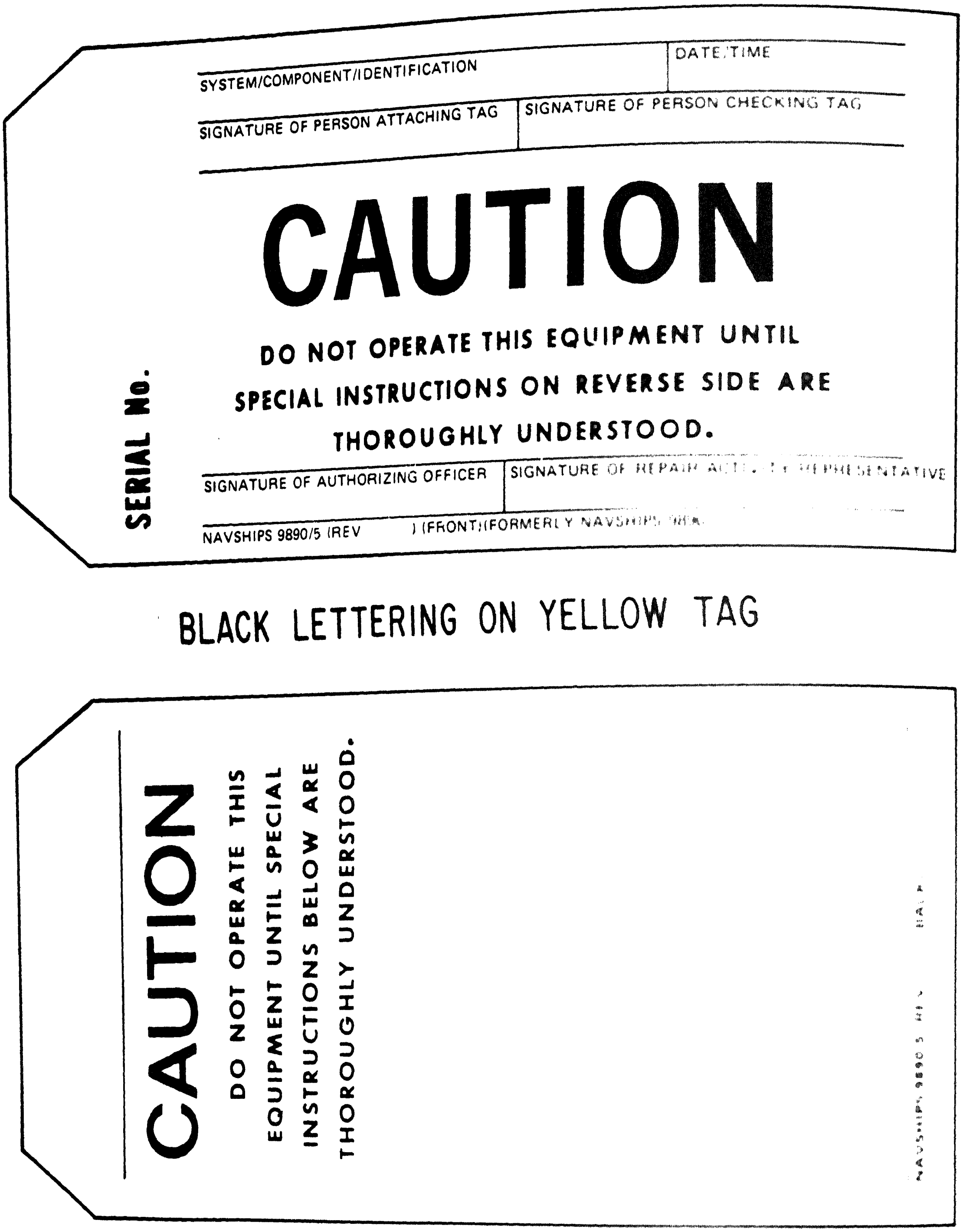
Outstanding tag-outs are spot checked periodically. An audit of the tag-out log is held every 2 weeks. Results of the audit are reported to the engineer officer.

To ensure that tag-out procedures are enforced properly, the engineer officer checks the log frequently. If he notes any errors, he brings them to the attention of the proper personnel.

ELECTRICAL SAFETY

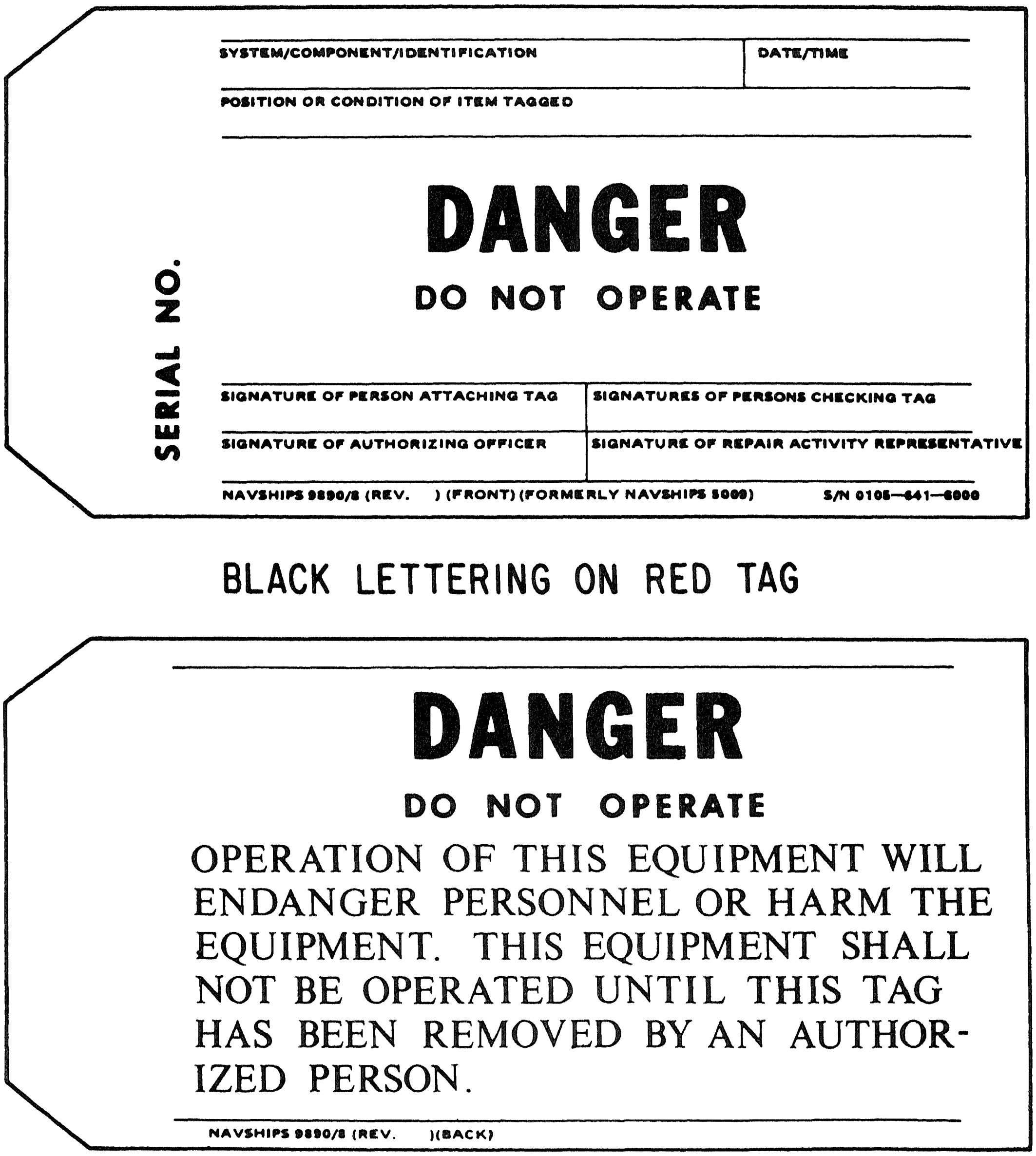
Accidents can be prevented. It is your job to recognize unsafe conditions and see that they are corrected. Observing safety precautions helps keep your equipment operating, helps your career in the Navy, and possibly determines whether you survive.

Think safety. No person is safer than the most careless act performed. Safety is stressed in numerous places throughout this rate training manual. For a more complete reference of detailed safety precautions use *Naval Ships' Technical Manual*, Chapters 300 and 400; OPNAVINST 3120.32, *Standard Organization and Regulations*



67.329

Figure 1-7.—Caution tag (colored yellow).



67.330

Figure 1-8.—Danger tag (colored red).

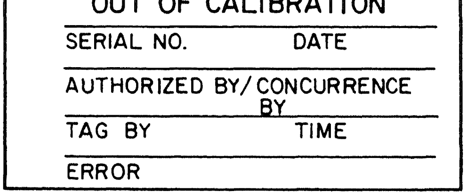


Figure 1-9.—Out-of-calibration label.

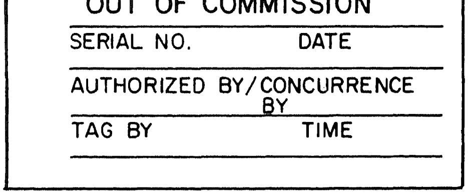


Figure 1-10.—Out-of-commission label.

40.67

Figure 1-11.—Safety posters.

of the U.S. Navy (SORM); and OPNAVINST 5100.19, *Safety Precautions for Forces Afloat.*

Electrical Hazards and Precautions

It is important that you recognize a hazardous electrical condition and take immediate steps to correct it. Safety posters (figures 1-11 and 1-12) help warn of dangers in working areas or help remind you to be safety conscious. Warning signs (red) and caution signs (yellow) should be located where hazardous conditions exist.

The danger of shock from the 450-volt a.c. ship's service system is reasonably well recognized by operating personnel. This is shown by the relatively few reports of serious shock received from this voltage, despite its widespread use. On the other hand, a number of shipboard fatalities have been reported due to contact with 115-volt circuits. Low-voltage (115 volts and below) circuits are very dangerous and can cause death. This is most likely to happen when the resistance of the body is lowered by moisture and especially when current passes through or across the chest. Extra care and awareness of the hazards associated with normal shipboard conditions must be emphasized. Perspiration and/or damp clothing result in a decrease in the resistance of the human body. Low body resistance along with the ship's metal structure are the breeding grounds for severe electrical shock.

Short circuits can be caused by accidentally placing or dropping a metal tool, rules, flashlight case, or any other conducting article across an energized line. The arc and fire that may result on even relatively low-voltage circuits can cause extensive damage to equipment and serious injury to personnel.

Since the ship's service power distribution systems are designed to be ungrounded, many personnel believe it is safe to touch one conductor since no electrical current flows. This is not true. If one conductor of an ungrounded system is touched while the body is in contact with the ship's hull or other metal equipment enclosure, a fatal electric current may pass through the body. ALL LIVE ELECTRIC CIRCUITS SHALL BE TREATED AS HAZARDOUS AT ALL TIMES.

Wear rubber gloves and protective clothing wherever working conditions warrant it. Make it a habit to look for and correct defective tools and equipment, improper grounding, and rotating machinery hazards.

Hand Tools

Normally, you should have no problems when working with hand tools. In all likelihood, however, you have seen some dangerous practices in the use of hand tools that should have been avoided. One unsafe practice involves the use of tools with plastic or wooden handles that are cracked, chipped, splintered, broken, or otherwise unserviceable. This practice is sure to result in accidents and personal injuries such as cuts and bruises, and foreign objects being thrown in the eyes. If these unserviceable hand tools are not repairable, they should be discarded and replaced.

When necessary (in an emergency only) to improvise an insulated hand tool, use the following approved method that can protect the user against the effects of electric shock. First, apply several layers of approved rubber insulating tape on the metallic handle. Next, apply a layer or two of friction tape over the insulating tape. When used alone, friction tape does not provide adequate protection from electrical shock, It should be used only for gripping purposes and to protect the insulating tape. For other instructions on the safe use of hand tools, consult *Tools and Their Uses*, NAVEDTRA 10085-B.

Portable Electric Power Tools

Portable power tools should be clean, properly oiled, and in good repair. Before they are used, inspect them to see that they are properly grounded. The newer, double-insulated plastic framed tools do NOT have ground wires and have only a two-prong plug.

If a tool is equipped with a three-prong plug, it should only be plugged into a three-hole electrical receptacle.

Never remove the third prong. Make absolutely sure the tool is equipped with a properly grounded conductor. If the tool has a metal case, be sure to ground it according to chapter 300 of *Naval Ships' Technical Manual*. Observe safety precautions and wear rubber gloves whenever plugging into any 115-volt circuit, when operating any portable electric equipment under particularly hazardous conditions, in environments such as

Figure 1-12.—Safety posters. 40.67(77(

wet decks, bilge areas, or when working over the side in rafts or small boats.

Before issuance of any portable electrical equipment, visually examine the attached cable with plug (including extension cords, when used) to assure it is in satisfactory condition. (Tears, chafing, exposed insulated conductors, and damaged plugs are causes for cable or plug replacement.) Then test the equipment with its associated extension cords connected. Make the test using an approved tool tester or by plugging the equipment into a dummy (or de-energized) receptacle and testing it for resistance from equipment housing to ship's structure with an ohmmeter (the resistance must be less than 1 ohm). Move or work cable with a bending or twisting motion. A change in resistance indicates broken strands in the grounding conductor. If this is found, replace the cable. It is further suggested that, at the discretion of the commanding officer, a list be established of portable equipment requiring testing more or less often than once a month depending on conditions in the ship. Where PMS is installed, conduct tests following instructions on the maintenance requirement cards.

Other safe practices in the use of portable electric power tools include the following:

- Inspect the tool cord and plug before using the tool. Do not use the tool if its cord is frayed or its plug is damaged or broken. Do not use spliced cables except in an emergency that warrants the risk involved.

- Before using the tool, lay all portable cables so you and others cannot trip over them. The length of extension cords used with portable tools should not exceed 25 feet. Extension cords of 100 feet are authorized on flight and hangar decks. Extension cords of 100 feet are also found in damage control lockers, but are labeled for *Emergency Use Only*.

- Do not use jury-rigged extension cords that have metal "handy boxes" for receptacle ends of the cord. All extension cords must have nonconductive plugs and receptacle housings.

- Connect the tool cord into the extension cord (when required) before inserting the extension cord into a live receptacle.

- After using the tool, first unplug the extension cord (if any) from the live receptacle before unplugging the tool cord from the extension cord. Do not unplug a cord by yanking on it.

- Stow the tool in its assigned place after you are through using it.

FIRST AID FOR ELECTRIC SHOCK

All shipboard personnel should be made aware that a victim rendered unconscious by electric shock should receive artificial respiration and that it should be started in a matter of seconds rather than minutes. Records show that seven out of ten victims of electric shock were revived when artificial respiration was started in less than 3 minutes. After 3 minutes, the chances of revival decrease rapidly.

The person nearest the victim should start the resuscitation without delay and call or send others for assistance and medical aid. The only logical permissible delay is that required to free the victim from contact with the electricity in the quickest, safest way. This step, while it must be taken quickly, must be done with great care. Otherwise, there may be two victims instead of one. This should be done in the case of portable electrical tools, lights, appliances, equipment, or portable outlet extensions by turning off the bulkhead supply switch or by removing the plug from its bulkhead receptacle. If the switch or bulkhead receptacle cannot be located quickly, the suspected electric device may be pulled free of the victim. Clearly warn other persons arriving on the scene not to touch the suspected equipment until it is de-energized. Enlist aid to unplug the device as soon as possible. If the victim is in contact with stationary equipment such as a bus bar or the contacts on a machine, pull the victim free if the equipment cannot be quickly de-energized, or if conditions of military operation or ship survival prevent immediate shutdown of the circuits.

The victim can be quickly and safely cleared from contact with electricity by carefully applying the following procedures:

- Protect yourself with dry insulating material.

- Use a dry board, belt, dry clothing, or other available nonconductive material to free the victim from the live wire. DO NOT TOUCH THE VICTIM.

RESUSCITATION FOR ELECTRIC SHOCK

Artificial resuscitation after electric shock includes artificial respiration to reestablish breathing and external heart massage to reestablish heartbeat and blood circulation. To aid a victim of electric shock after removing him from contact with the electricity, immediately apply mouth-to-mouth resuscitation (see all parts A and B of figure 1-13). If there is no pulse, apply heart massage also (see part C of figure 1-13). Don't waste precious seconds carrying the victim from a cramped, wet, or isolated location to a roomier, dryer, more frequented location. If desired, breathe into the victim's mouth through a cloth or a handkerchief placed over the victim's face. If assistance is available, take turns breathing into the victim and massaging his heart.

Cardiac Arrest (Loss of Heartbeat)

If the victim has suffered an electric shock and has no heartbeat, he has a cardiac arrest. This can be demonstrated by finding a complete absence of any pulse at the wrist or in the neck. Associated with this, the pupils of the eyes are very dilated and respiration is weak or stopped. The victim may appear to be dead. Under these circumstances, severe brain damage occurs in 4 minutes unless circulation is reestablished by cardiac massage.

Closed Chest Cardiac Massage

Closed chest cardiac massage has been adopted as practical. With proper instruction, it can be learned by anyone. It requires only two hands. The object in closed chest cardiac massage is to squeeze the heart through the chest wall, emptying it to create a peripheral pulse. This must be done about 60 times each minute. Use the following steps for closed chest cardiac massage.

1. Place the victim on his back; a firm surface, such as the deck, is preferred. Expose the victim's chest.

2. Kneel beside the victim; feel for the end of the victim's sternum (breastbone); one hand across the breastbone so the heel hand covers the lower part; place the second on top of the first so the fingers point towa neck (as in part C of figure 1-13).

3. With arms nearly straight, rock forw a controlled amount of your body wei transmitted through your arms and hands breastbone. The amount of pressure to varies with the victim. It should be appli smoothly as possible. With an adult victin chest wall should be depressed 2 to 3 inche each pressure application.

4. Repeat application of pressure about 80 times per minute.

5. An assistant should be ventilatin victim's lungs, preferably with pure oxygen intermittent positive pressure—otherwise mouth-to-mouth resuscitation. However, c chest massage causes some ventilation o lungs.

6. Direct other assistants, when availab keep checking the patient's pulse. Use the pressure that secures an effective pulse beat pupils should become smaller when effe cardiac massage is being performed.

7. Pause occasionally to determine if a s taneous heartbeat has returned.

NOTE: Make every effort to keep the h positioned as described above to prevent inj to the liver, ribs, or other vital organs. S the heart cannot recover unless supplied oxygenated blood, it is necessary to accom cardiac massage with mouth-to-mouth resus tion. When there is only one operator, cardiac massage must be interrupted every minute or so to institute rapid mouth-to-m breathing for three or four respirations.

HEAT STRESS

During exposure to warm climates, w working in hot environments, or during stren physical work in cool as well as hot ambient ditions, personnel are apt to suffer heat disor The results are loss of time from duty possible death. Many of these illnesses resu prolonged or permanent impairment of affected person's ability to withstand h

A

ARTIFICIAL RESPIRATION

MOUTH-TO-MOUTH OR MOUTH-TO-NOSE
RESCUE BREATHING

① **PLACE CASUALTY ON BACK IMMEDIATELY**
DON'T WASTE TIME MOVING TO A BETTER PLACE OR LOOSENING CLOTHING.

② **QUICKLY CLEAR MOUTH AND THROAT**
REMOVE MUCUS, FOOD AND OTHER OBSTRUCTIONS.

③ **TILT HEAD BACK AS FAR AS POSSIBLE**
THE HEAD SHOULD BE IN A "CHIN-UP" OR "SNIFF" POSITION AND THE NECK STRETCHED.

④ **LIFT LOWER JAW FORWARD**
GRASP JAW BY PLACING THUMB INTO CORNER OF MOUTH. DO NOT HOLD OR DEPRESS TONGUE.

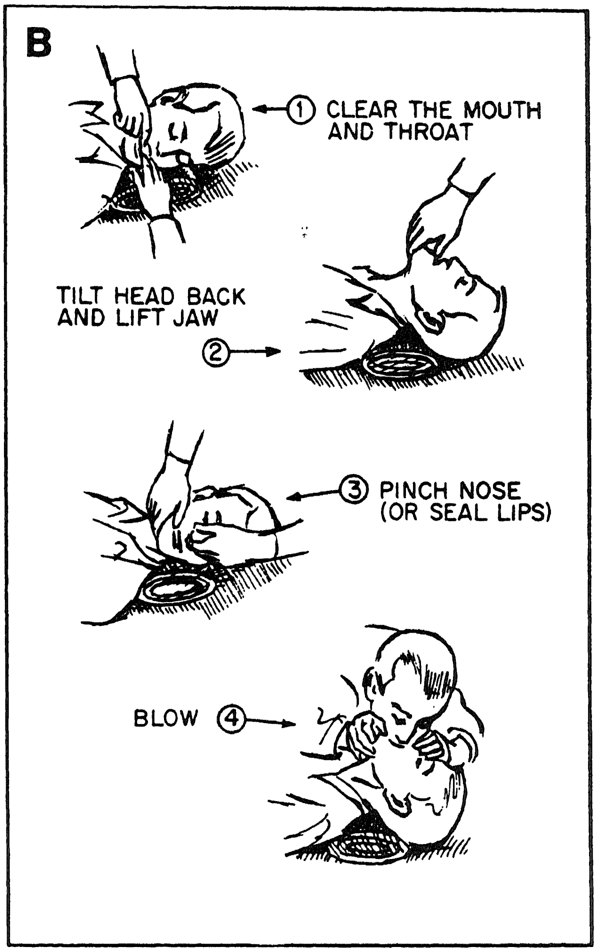
⑤ **PINCH NOSE SHUT OR SEAL MOUTH**
PREVENT AIR LEAKAGE.

⑥ **OPEN YOUR MOUTH WIDE AND BLOW**
TAKE A DEEP BREATH AND BLOW FORCEFULLY (EXCEPT FOR BABIES) INTO MOUTH OR NOSE UNTIL YOU SEE CHEST RISE.

⑦ **LISTEN FOR EXHALATION**
QUICKLY REMOVE YOUR MOUTH WHEN CHEST RISES. LIFT JAW HIGHER IF VICTIM MAKES SNORING OR GURGLING SOUNDS.

⑧ **REPEAT STEPS SIX AND SEVEN 12 TO 20 TIMES PER MINUTE**
CONTINUE UNTIL VICTIM BEGINS TO BREATHE NORMALLY.

* **FOR INFANTS SEAL BOTH MOUTH AND NOSE WITH YOUR MOUTH**
BLOW WITH SMALL PUFFS OF AIR FROM YOUR CHEEKS.



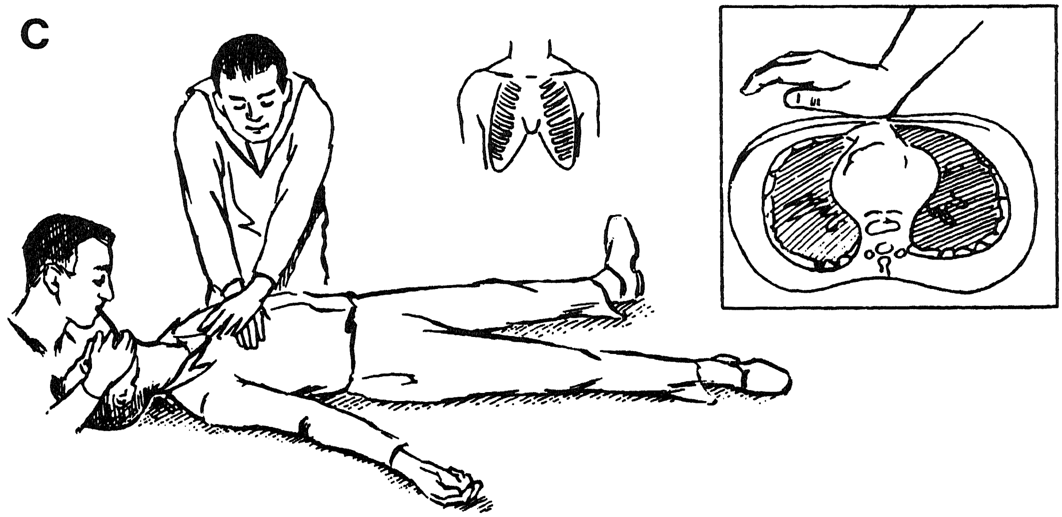


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Figure 1-13.—Artificial respiration and cardiac massage.

Unacclimatized and overweight personnel are particularly susceptible to heatstroke and other heat disorders.

Because of these hazards, exposure of personnel to extended periods of strenuous physical work in spaces of high ambient temperature must conform with BUMEDINST 6200.7.

NOISE POLLUTION

Control of noise emission is an important aspect of pollution control. Noise above certain sound levels can cause a wide variety of unwanted effects on personnel, ranging from discomfort and anxiety to illness and deafness. Because of these hazards, exposure of personnel to high sound levels must conform with DODINST 6055.3 of 8 June 1978 and the latest issue of OPNAVINST 6240.3.

Gas turbine engine-generated noise levels are on the order of 100 to 125 dB. These levels are sufficient to cause partial or total deafness to unprotected personnel. Three primary noise sources exist in a gas turbine installation. They are as follows:

1. The inlet passages
2. The exhaust ducts
3. The engine core

Noise from the first two sources, the inlet and exhaust ducts, can be controlled by the installation of acoustic insulation to the structure. To prevent negation of the soundproofing characteristics of structural insulation, the insulation must be constantly maintained at a high degree of repair.

Similar acoustic treatment should be applied to engines mounted in a compartmentalized shroud or enclosure. If such an enclosure or shroud is not installed, the entire compartment in which the engine is installed should be acoustically insulated.

Personnel working in an environment where the noise level is 84 dB or above must wear approved hearing protection. If you must be in an area where the noise level is 104 dB or above (such as running checks on a GTM with the module door open), double hearing protection must be worn—earplugs and earmuff protectors.

SYNTHETIC LUBE OIL

Because of the high rotational speeds and high temperatures generated by gas turbine engines, petroleum-based oils are not suitable for use. Synthetic-based oils containing polyol esters are normally used on today's gas turbine engines. These oils are usually less viscous than those used in reciprocating engines.

The synthetic oil in general use aboard gas turbine ships is MIL-L-23699. These oils can remove paint and are toxic; therefore, special precautions and handling procedures must be used.

When you are handling synthetic oils, you must avoid spills. Prolonged contact with the oil can cause skin irritations such as dermatitis. Inhalation of vapors can cause irritation of the respiratory tract. You should always wear a face shield, rubber gloves, and apron when working with this oil. If you do come in contact with synthetic oil, you should remove any oil-soaked clothing and wash with soap and water. If the oil is splashed into your eyes, immediately flush with water.

SUMMARY

This chapter has covered a wide variety of subjects to give you an overview of the gas turbine rating. All these areas are important in their own right. Some topics will be discussed in greater detail in later chapters. You should study the occupational standards and the other publications mentioned in this chapter to become a more proficient and reliable technician.

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CHAPTER 2

TOOLS AND TEST EQUIPMENT

As a GSE, you will be working with electrical and electronic equipment. Your responsibilities include the routine maintenance of the electrical and electronic equipment in your engineering spaces. After reading this chapter, you should be able to describe some of the devices you may use during your maintenance procedures. The devices discussed in this chapter are not all the tools and equipment that a GSE might use. For further information refer to *Tools and Their Uses*, NAVPERS 10085-B and Navy Electricity and Electronics Training Series (NEETS), Modules 1, 3, and 16. Be sure to refer to the appropriate manufacturer's technical manuals, the naval ships' technical manuals, and/or information books to determine the specific device recommended for each procedure.

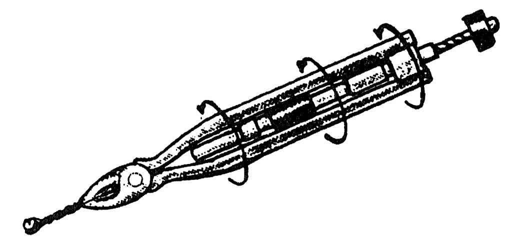

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Figure 2-1.—Wire-twister pliers.

HANDTOOLS

Everyone has used a handtool at one time or another for some type of job. The types of handtools described in the following sections are some that you might use, but with which you possibly are not familiar.

WIRE-TWISTER PLIERS

Wire-twister pliers (figure 2-1) are three-way pliers which hold, twist, and cut. They are designed to reduce the time used in twisting safety wire on nuts and bolts. To operate, grasp the wire between the two diagonal jaws, and use your thumb to bring the locking sleeve into place. When you pull on the knob, the twister twirls and makes uniform twists in the wire. You can push back the spiral rod into the twister without unlocking it. Then another pull on the knob will give a tighter twist to the wire. A squeeze on the handle unlocks the twister. Now you can cut the wire to the desired length with the side cutter. Occasionally lubricate the spiral of the twister.

Examples of safety-wiring techniques that you should follow when using wire-twister pliers are shown in figures 2-2 and 2-3. Although all possible safety-wiring combinations are not shown, safety-wiring practices should conform to those shown. Consult specific manufacturers' technical manuals for approved materials and techniques to use in any given application. You will find step-by-step procedures for safety-wiring in *Propulsion Gas Turbine Module LM2500, Trouble Isolation*, Volume 2, Part 3, S9234-AD-MM0-050/LM2500, section 8.1.

WRENCHES

While performing your maintenance procedures, you will use a variety of wrenches. This

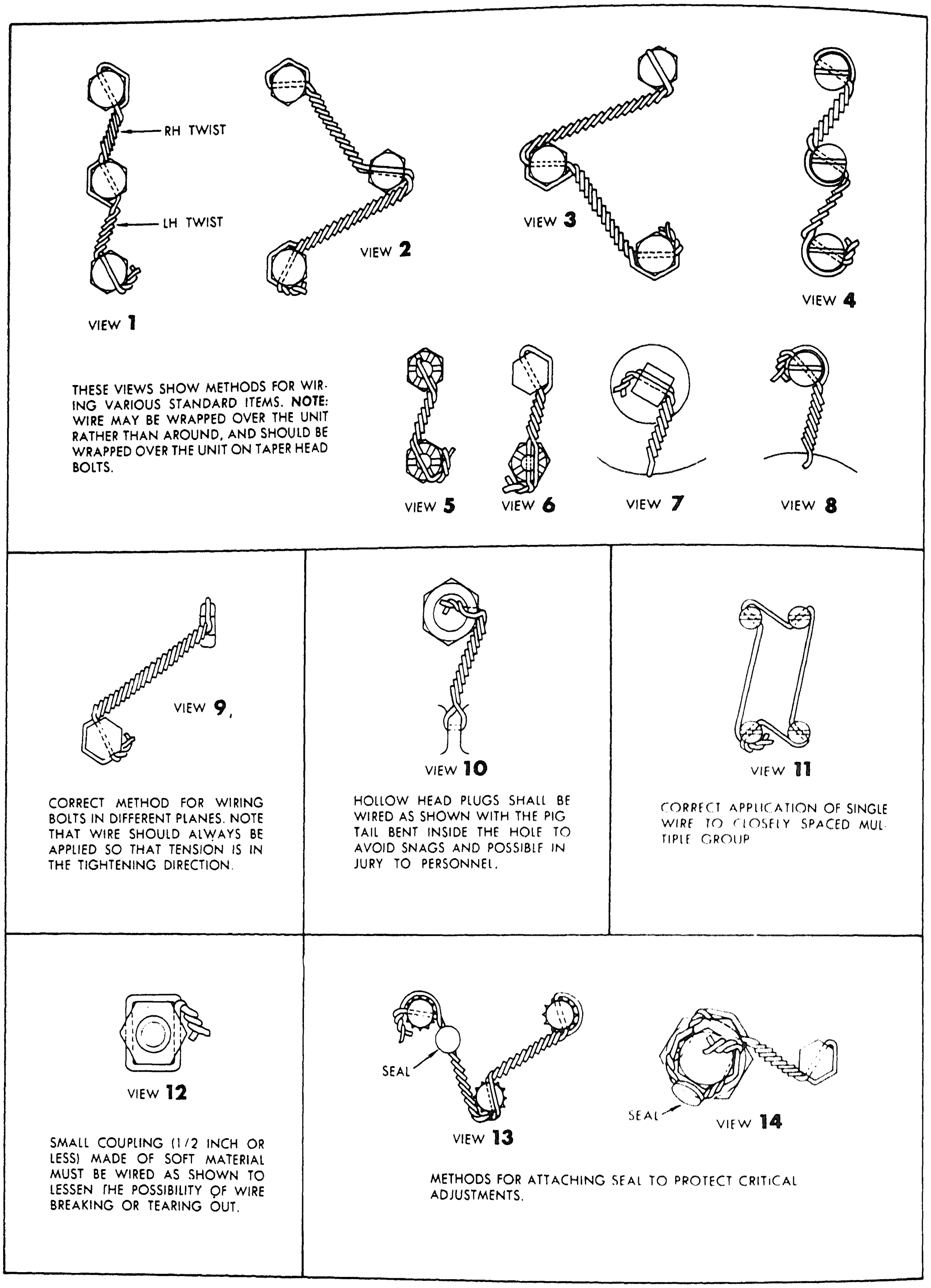

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Figure 2-2.—Safety-wiring practices.

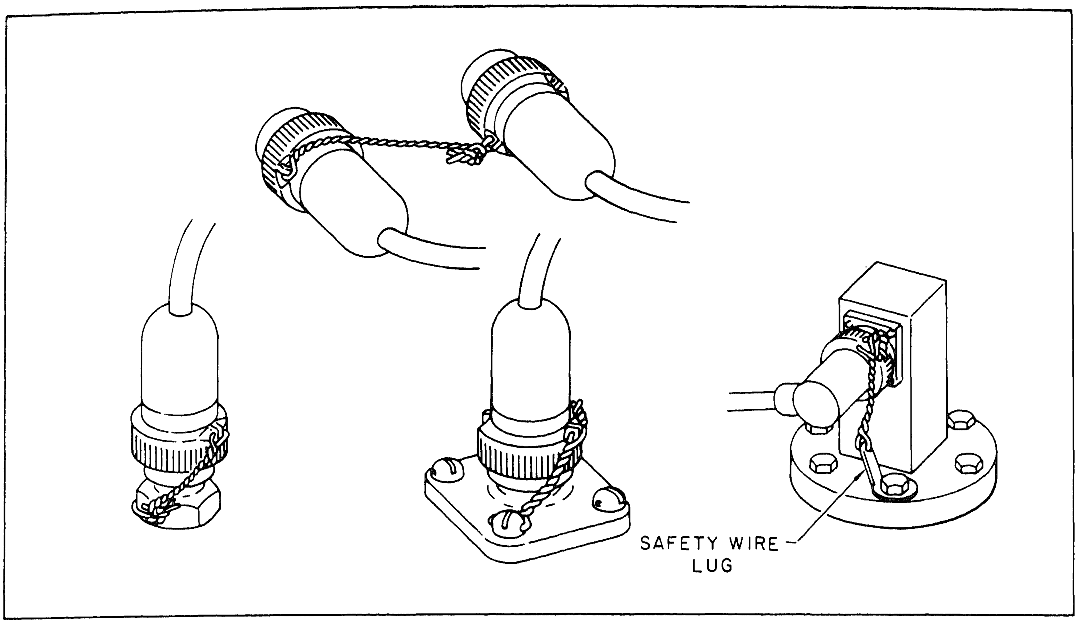

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Figure 2-3.—Safety-wiring electrical connectors.

section is about the recommended wrenches you need to be familiar with while working on the gas turbine engine. You will also learn about wrenches and handtools that are not recommended for use on the gas turbine (GT) engine.

Recommended Wrenches

The CROWFOOT wrench, figure 2-4, is a very handy tool to use for maintenance procedures. It is used to gain accessibility in hard to reach areas where other wrenches are difficult to use. The head of the wrench is designed like an open-end wrench. However, the other end is designed to accommodate accessories such as extensions, breaker bars, and torque wrenches. Crowfoot wrenches come in a wide variety of sizes like those of the open-end type of wrenches.

The FLARE NUT wrench, figure 2-4, is similar to a box wrench. The difference is a slot cut in the wrench head which allows it to fit over tubing or wiring and then onto the fastener. There are two types of this wrench you might use on your ship. The first type is long handled, similar to the regular box wrench, with a different size on each end. The second type is short, with the opposite end allowing it to be used with extensions, breaker bars, and torque wrenches. These flare nut wrenches are made with 6, 8, 12, and 16 points or notches. The wrenches on your ship will generally be 12 points because of the numerous 12-point fasteners used on the gas turbine engine. The 12-point wrench can also be used effectively on 6-point (hex head) fasteners when needed. As with the crowfoot wrenches, the flare nut wrenches come in a wide variety of sizes.

Nonrecommended Wrenches and Handtools

The adjustable wrench and cadmium-plated or silver-plated tools are NOT recommended for use while working on gas turbine engines. You might, however, use them elsewhere for maintenance.

The ADJUSTABLE wrench is useful because it will fit nuts and bolts that are odd-sized or slightly damaged or burred. BUT good engineering practice dictates that you use the proper size wrench for the work you are doing.

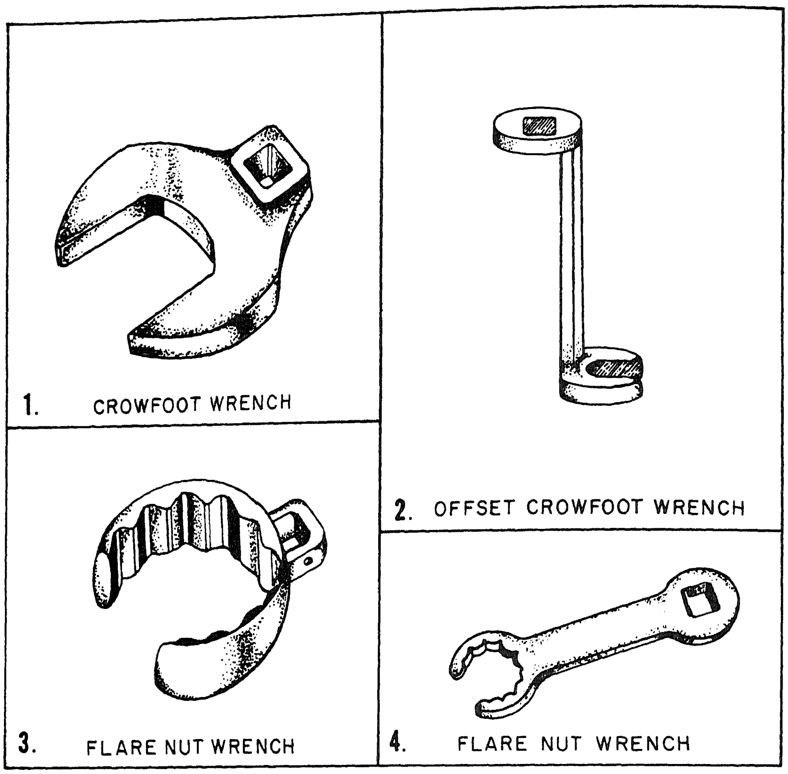

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Figure 2-4.—Crowfoot and flare nut wrenches.

Parts on the gas turbine engines are made of high-quality materials and are standard sizes. Because of the design of the adjustable wrench, it could cause extensive damage to the gas turbine engine. If it slips, gouging and/or scratching could occur. Do not use a part if it is damaged in any way.

DO NOT use CADMIUM-PLATED or SILVER-PLATED handtools when working on titanium parts of gas turbine engines. If you use these handtools, you could cause particles of cadmium or silver to become imbedded in the titanium parts. At temperatures above 600 °F the cadmium or silver can cause embrittlement. This results in overstressed areas and possible cracking. To prevent this, use chrome-plated, nickel-plated, or unplated handtools on titanium parts.

WIRE-WRAP HANDTOOLS

Basically, wire wrapping is simply winding a solid wire tightly around a stiff pin to provide a good junction. Figure 2-5 shows some of the types of handtools currently available for this purpose. Wire-wrap handtools are used with different sized bits and sleeves depending on the size of the wire being used. Some ships have wire-wrap kits for the GSEs. On other ships you might need to borrow these handtools from other divisions such as the Data Systems Technicians or the Fire Control Technicians.

The equipment using the wire-wrap technique have long square pins at the rear of the female connectors used for logic card inserts. An example is the back-planes of various consoles. These pins are long enough to allow one to three wires to be wrapped on them in separate

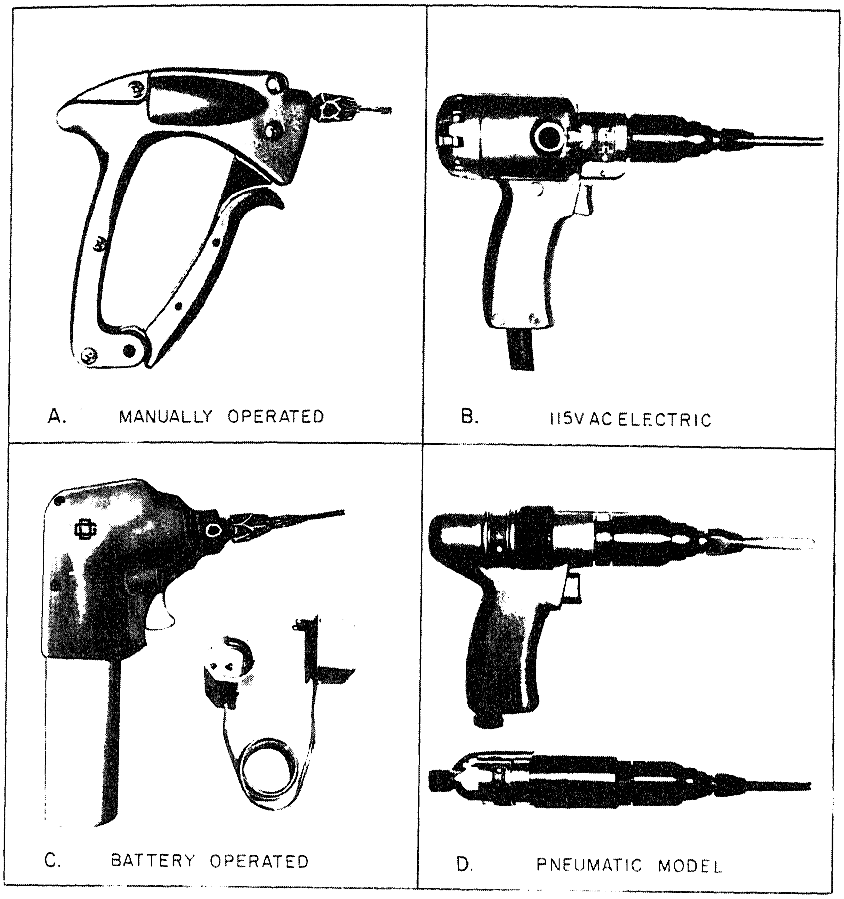

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Figure 2-5.—Examples of wire-wrap tools.

aps. (A "wrap" is defined here as a series of ns of a single solid wire about a post.) The nale connectors are then interconnected from to pin by a small, solid insulated wire. This ulated wire may or may not be color coded. chine-wrapped assemblies usually do not con- n color-coded wiring. Hand-wired assemblies . (Color-coded wire is an advantage in hand- ed assemblies, since each wire becomes more tinctive and fewer errors are likely to result.)

re-Wrap Principles

The principle behind wire wraps is a simple . For proper conduction to occur between two tals, first penetrate the oxide coating that has med on both surfaces. As mentioned above, the pins used in the wire wraps are squared off. They have corner edges that will penetrate the oxide coating of the wire when it is properly wound on the pin. The edges will also lose their oxide coating when they penetrate the surface of the wire. The junction that is formed is strong, gastight (tight enough to seal out gases, in addition to liquids), and resistive to corrosion.

Wire-Wrap Techniques

The technique of wire wrapping is also fairly simple. A special solid conductor insulated wire is required. The use of solid conductor wire ensures that the coil will form tightly about the pin and remain that way without appreciable slippage. The wire is a composition of a silver

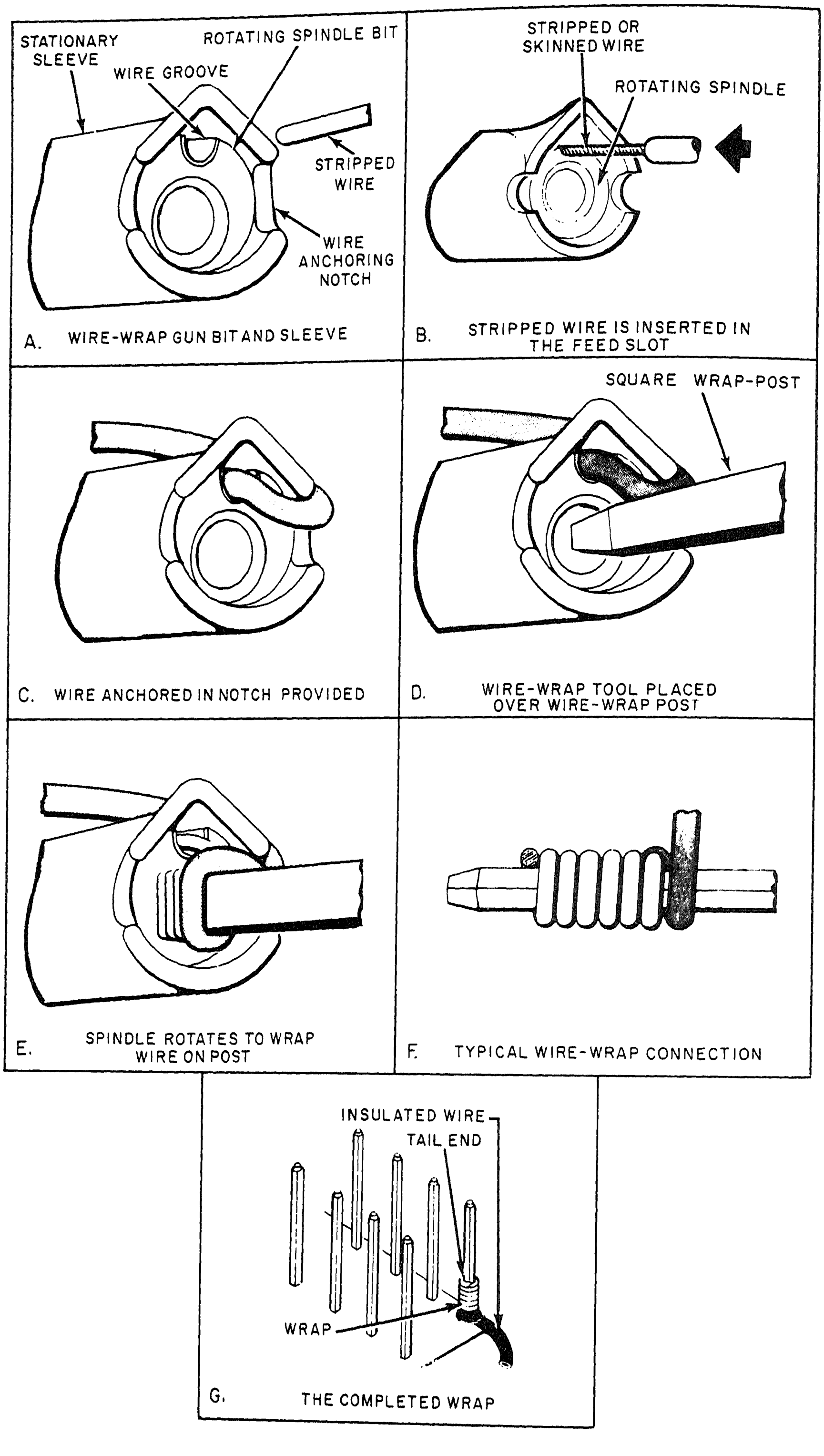

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Figure 2-6.—Basic wire-wrap procedure.

loy with a copper coating. Silver offers an lvantage in that its oxide is almost as conducve as the pure metal. Teflon or Meline is usually e insulation used on the wire. Teflon offers an lvantage of very high temperature stability and ise of cutting (for stripping by automatic achinery). It also has the undesirable trait of adually flowing away from any point of conued pressure—a process described as "cold ow." Teflon-insulated wire in contact with a pin ay eventually result in an intermittent short curring at that point. Meline withstands conued exposure to pressure much better than eflon. It is more resistive to cold flow, but does t have the very high temperature characteristics Teflon. Meline has become more widely used ecause of the cold flow problem.

The first step in wire wrapping is for you to termine the correct gauge of wire required to rform the job. Strip off enough insulation to low the correct number of turns to be wound ound the pin. Then place the end of the wire either a long shallow groove along the barrel the wire-wrap tool, or insert it in the smaller le at the end of the barrel (figure 2-6, item A). ie groove (or hole) for the wire is carefully zed to provide the exact amount of tension needto form a secure wrap. Ensure the insulation ttoms in the wire funnel as shown in item B of e figure. This will allow you to wrap the corct amount, (1-11/2 turns) of insulated wire ound the wrap post. Anchor the wire by nding it into the notch in the sleeve as shown item C. The center hole at the end of the rrel is next slipped down over the pin, item D. hen the barrel is rotated about the pin, the wire ll twist around the pin, item E. As the wire ists around the pin, the stripped portion of the re that is being held in the groove (or in the her base hole) will be drawn down to twist and il around the pin. The barrel of the wire-wrap ol rotates as a result of finger, hand, or motor tion. The action depends upon the tool's design. ie coiling action of the wire on the pin lifts the ol enough to continue the wire coil up the pin. owever, too much pressure on the tool will cause e coils to "bunch," or overlap. If you are placing a wire, carefully run the wire to the next nnection and perform the same procedure on e opposite end. Be sure you allow enough cess wire for the wraps needed on the post.

Before actually doing a wire wrap on the item that you are repairing, take time to practice this procedure. Find a spare connector or spare pin, similar to those you are repairing. Using the same materials that are required for the actual job, practice a few times. A good wire wrap can be identified (figure 2-7, item A) by four to seven and a half snug turns of wire. Place the insulation about the bottommost one or two turns with no spacing between adjacent turns, no bunching as one turn attempts to cover another, and no observable nicks in the wire. The number of turns is determined by the wire gauge. Larger diameter wires and pins require fewer turns, and smaller diameters mean more turns.

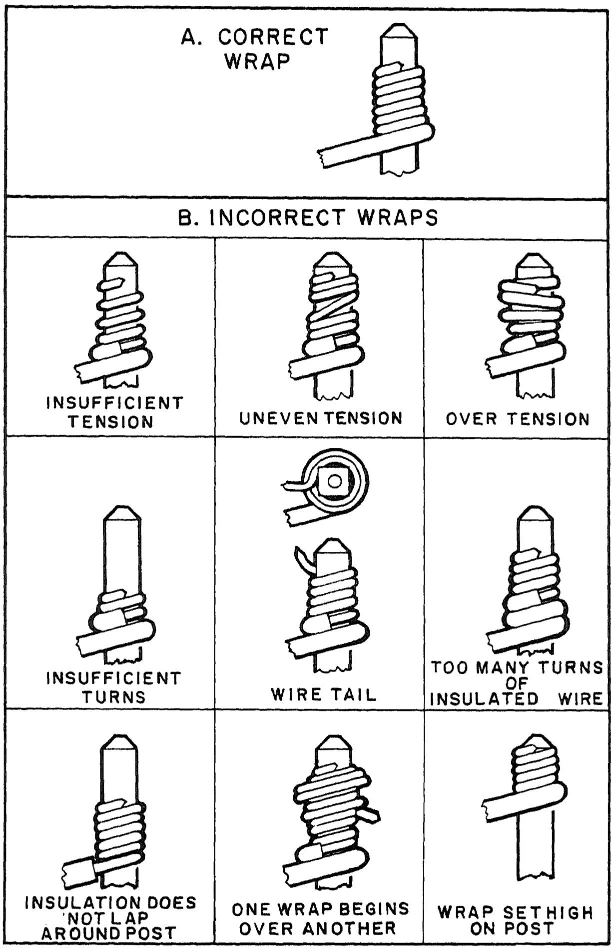

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Figure 2-7.—Correct versus incorrect wire wraps.

The following is a list of a variety of INCORRECT methods of wire wrapping:

1. Insufficient tension on wire—results in loose connection (detected by open spaces between adjacent turns)
2. Overtension on wire—results in loose connection (detected by turn overlaps and insufficient surface contact with the pin)
3. Insufficient number of turns (less than five)—poor contact (insufficient wire was stripped first)
4. Insulation does not extend to pin—increased chances of shorts or wire breaks (too much wire was stripped)
5. Reuse of an uncoiled wrap—each reuse increases likelihood of wire breaks
6. Attempts to wrap by hand—insufficient and uneven tension results in poor contact.

The most common faults are visually identified in figure 2-7, item B.

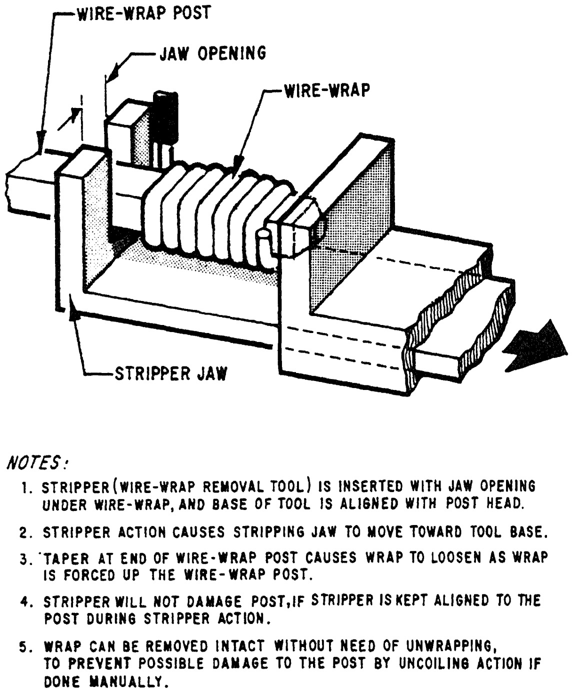

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Figure 2-8.—Wire-wrap removal with wire-wrap removal tool.

Wire wraps are normally removed with a wire-wrap removal tool (figure 2-8). This prevents stress and possible damage to the wire-wrap post. However, if you have to remove the wire by hand, unwrap the wire without applying stress to the post. You can best accomplish this by gently uncoiling the wire with a slight rotating movement over the point of the post. Make sure that the manner in which the wire is removed does not cause movement of the post itself (figure 2-9). If a post is bent, it will probably break when an effort is made to straighten it. If a post breaks, you first make sure that the broken length is not left in the wiring to cause possible shorts. Then take the necessary steps to install a new post. Normally, inner wire wraps are placed near the bottom of the post to ensure that additional wraps can be added easily. If you have to remove a lower wire wrap, first remove each wrap above it. Do not remove a wire wrap by trying to pull it along its axis (see figure 2-9). Remember, each wrap is easily identified because it is formed from the multiple turns of a single solid wire.

When removing a wire wrap from a pin, you must be careful not to disturb other wraps on

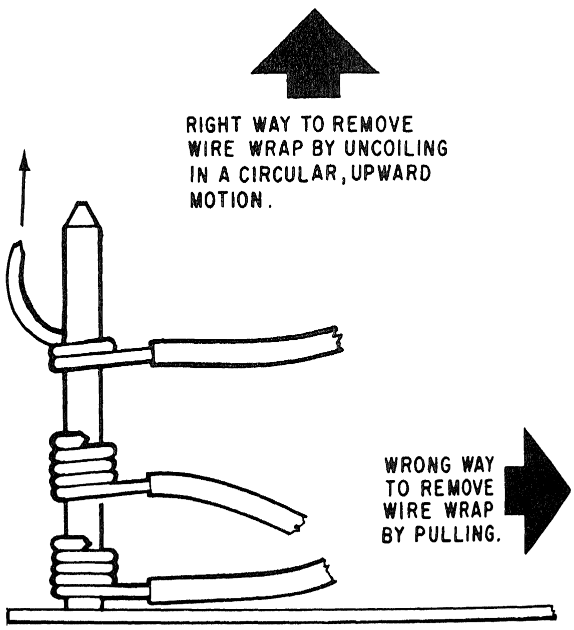

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Figure 2-9.—Method of removing a wire wrap manually.

same or adjacent pins, or to dislodge the pin. is would cause poor continuity or an open cuit.

ADVANTAGES.—Some of the advantages of e wraps are:

1. Simplified technique for repairs (wires are rely uncoiled to remove and replaced with the oper simple tools)
2. No solder spill (makes repairs possible hout removing components)
3. No danger of components overheating as ing soldering
4. More in-equipment repairs and faster air times
5. No danger of burning personnel (as from ot soldering iron)
6. Durable electrical contact (as good as have n achieved with good soldering technique, and erior to those connections made with poor dering technique)

DISADVANTAGES.—Some of the disadvan- es of wire wraps are:

1. Use of solid wire (increased likelihood of wire breakage)
2. Problems with insulation
3. Unsuitable to subminiature assemblies
4. Lack of a wire color code in machine-wrapped assemblies
5. The necessity of clipping off the wrapped portion of the wire and stripping the insulation back to expose new wire in making the next wrap. (If the wire is too short to permit this, it must be replaced. The reason the same portion of wire is not reused in the new wrap is that this area will have been weakened structurally by nicks from its previous use, and will be weakened further if reused.)

A number of useful tools, and techniques for ng them, have been developed for doing wire aps. We have discussed only some of them. An ellent text on wire-wrapping techniques is Code nt 10001 NAVORD Od 23446, *Wire-Wrap semblies, Description and Use of Tools and cumentation*. This ordinance manual is used the Fire Control Technicians (FTs). Another document that covers wire-wrap techniques is MILSTD (military standard) 1130B, notice 1, 19 July 1979, *Connections, Electrical, Solderless, Wrapping*.

Use caution in working with wire-wrap assemblies. These assemblies look like a bed of nails, and people have been injured by simply not taking precautions. A number of injuries occur to the face when the technician attempts to get a good look at the assembly from the side. This exposes the eyes to a needless hazard. Use sufficient lighting to make out details, small mirrors where feasible, and wear safety goggles if a firsthand view from this position is necessary. When inspecting/repairing the back-planes or areas of possible damage, remember that a.c. or d.c. voltages may still be present. Ensure proper safety precautions are followed for working with energized equipment.

INSPECTION MIRRORS

Inspection mirrors are helpful when you need to see into hard to reach areas. You can use them for inspections as well as actual maintenance.

Several types of inspection mirrors are available. The mirror comes in a variety of sizes and is either round or rectangular. It is connected to the end of a rod and may be fixed or adjustable (figure 2-10).

The inspection mirror aids in making detailed inspections where the human eye cannot directly see the inspection area. By angling the mirror, and with the aid of a flashlight, you can inspect most required areas. A late model inspection mirror features a built-in light to aid in viewing those

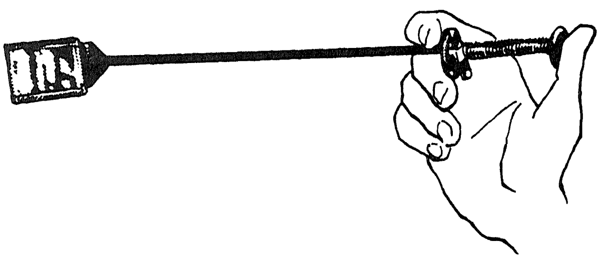

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Figure 2-10.—Adjustable inspection mirror.

dark places where use of a flashlight is not convenient.

HYDROMETERS

As a GSE, you will be responsible for maintaining the batteries for the Uninterruptible Power Supply (UPS). This section will not cover the batteries, but the tool required to check them. We will discuss batteries in chapter 11, Uninterruptible Power Supply (UPS).

A hydrometer is the instrument used to measure the amount of active ingredients in the electrolyte of the battery. The hydrometer measures the SPECIFIC GRAVITY of the electrolyte. Specific gravity is the ratio of the weight of the electrolyte to the weight of the same volume of pure water. The active ingredients, such as sulfuric acid or potassium hydroxide, are heavier than water. Because the active ingredient is heavier than water, the more active ingredient there is in the electrolyte, the heavier the electrolyte will be; the heavier the electrolyte, the higher the specific gravity.

A hydrometer, shown in figure 2-11, is a glass syringe with a float inside it. The float is a sealed, hollow glass tube weighted at one end. Marked on the side of the float is a scale calibrated in specific gravity. Use the suction bulb to draw the electrolyte into the hydrometer. Make sure enough electrolyte is drawn into the hydrometer for the float to rise. Do not fill the hydrometer too much so that the float rises into the suction bulb.

Since the weight of the float is at its base, the float will rise to a point determined by the weight of the electrolyte. If the electrolyte has a large concentration of active ingredient, the float will rise higher than if the electrolyte has a small concentration of active ingredient.

To read the hydrometer, hold it in a vertical position and take the reading at the level of the electrolyte. Refer to the manufacturer's technical manual for battery specifications for the correct specific gravity ranges.

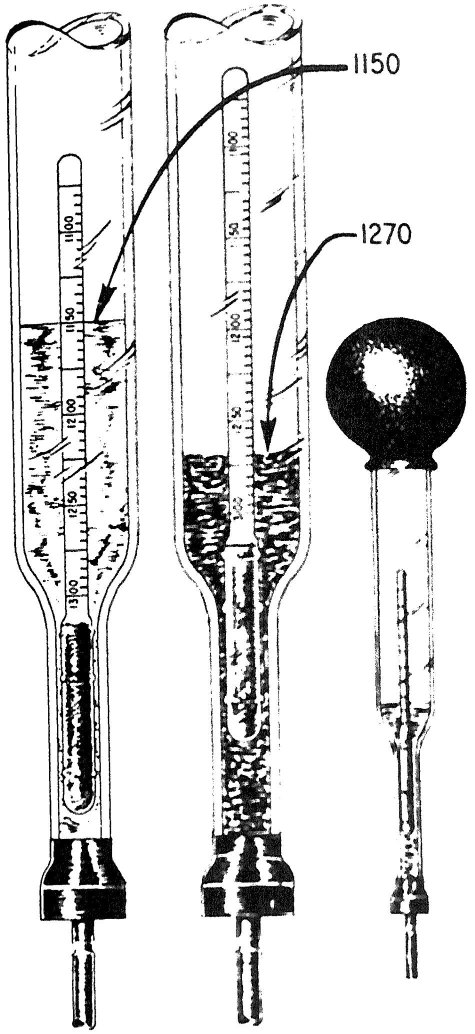

Figure 2-11. Hydrometer.

NOTE: Flush hydrometers with fresh
after each use to prevent inaccurate reading
not use storage battery hydrometers for any
purpose.

When working with batteries, ensure you
proper protective clothing; i.e., safety gl
rubber gloves, rubber apron, and rubber
The battery water contains acids which ca
clothes and cause severe burning. Be sur
follow the safety precautions found in
Ships' Technical Manual, Chapter 313, *Po
Storage and Dry Batteries*, and those fou
the PMS card.

PRECISION TOOLS

As a GSE, you will be required to use various precision tools while performing maintenance on the gas turbine engine. The torque wrench and power lever angle (PLA) actuator rigging tool set are covered in this section. The special gages for setting the power turbine speed transducer and the gas turbine generator set speed sensor are also covered.

TORQUE WRENCHES

GSEs are required to replace various parts of the gas turbine engine. Because of the wide range of temperatures associated with running and cooling down of the gas turbine engine, some parts are under a lot of stress. If parts are not tightened evenly and in a uniform manner, one or two bolts or fasteners could bear the brunt of the stress. This could result in damaged or broken parts. To prevent this, use a torque wrench when tightening the bolts or fasteners.

Types of Torque Wrenches

The three most commonly used torque wrenches are the deflecting beam, dial indicating, and micrometer setting types (figure 2-12). When using the deflecting beam and the dial indicating torque wrenches, the torque is read visually on a dial or scale mounted on the handle of the wrench.

The torque wrench you will probably use is the micrometer setting type. This type is easier to use because you don't have to watch a dial or pointer while using the wrench.

To use the micrometer setting type, unlock the grip and adjust the handle to the desired setting on the micrometer-type scale. Then relock the grip. Install the required socket or adapter to the square drive of the handle. Place the wrench assembly on the nut or bolt and pull in a clockwise direction with a smooth, steady motion. (A fast or jerky motion will result in an improperly torqued unit.) When the torque applied reaches the torque value, which is indicated on the handle setting, a signal mechanism will automatically issue an audible click. Next the handle will release or "break," and move freely for a short distance. The release and free travel is easily felt, so there is no doubt about when the torquing process is complete.

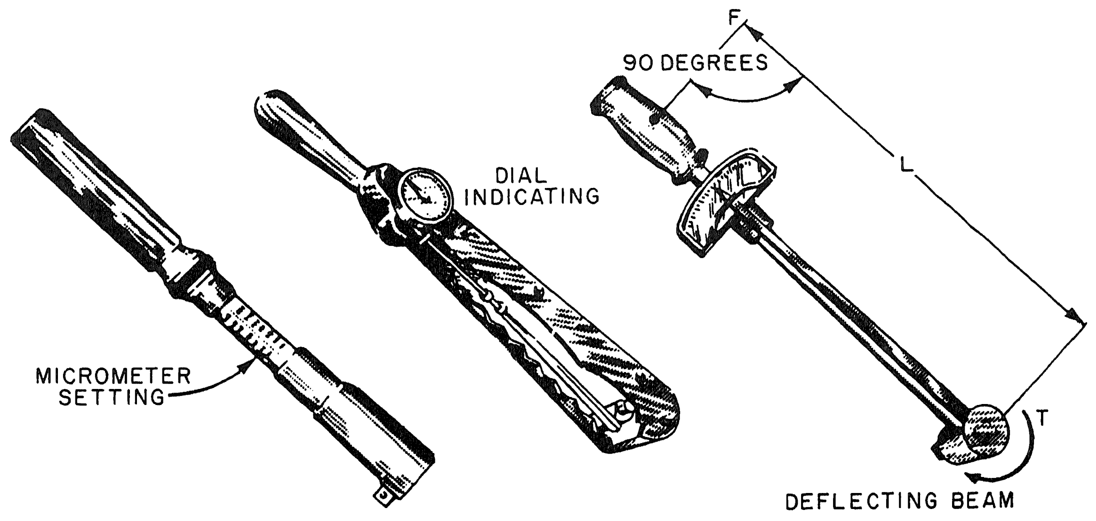

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Figure 2-12.—Torque wrenches.

The procedure for using the deflecting beam and the dial indicating wrenches is the same as above; however, you have to hold the torque at the desired value until the reading is steady.

Torque Values

Torque values are expressed in inch pounds (in-lb) or foot pounds (ft-lb). One inch pound (or 1 foot pound) is the twisting force of 1 pound applied to a twist-type fastener (such as a bolt or nut) with 1 inch (or 1 foot) of leverage. This twisting force is applied to the fastener to secure the components.

Manufacturers' technical manuals generally specify the amount of torque you should apply to fasteners. To assure getting the correct amount of torque on the fasteners, it is important to use a wrench following the manufacturer's instructions. Whenever you use an adapter (such as a crowfoot wrench) with a torque wrench, you must calculate the correct crowfoot torque. Figure 2-13 shows a step-by-step method to calculate torque.

Proper Use of Torque Wrenches

Use the torque wrench which will read about midrange for the amount of torque to be applied. BE SURE THAT THE TORQUE WRENCH HAS BEEN CALIBRATED BEFORE YOU USE IT. Remember, too, that the accuracy of torque-measuring depends a lot on how the threads are cut and the cleanliness of the threads. Make sure you inspect and clean the threads. If the manufacturer specifies a thread lubricant, you must use it to obtain the most accurate torque reading.

Torque wrenches are delicate and expensive tools. Observe the following precautions when using them:

1. Do not move the setting handle below the lowest torque setting when using the micrometer setting type. However, place it at its lowest setting prior to returning to storage.

2. Do not use the torque wrench to apply greater amounts of torque than its rated capacity.

3. Do not use the torque wrench to break loose bolts which have been previously tightened.

4. Do not drop the wrench. If you drop it, you will affect its accuracy, and it will need to be recalibrated before further use.

5. Do not apply a torque wrench to a nut that has been tightened. Back off the nut one turn with a nontorque wrench and retighten to the correct torque with the indicating torque wrench.

6. Do not use a torque wrench before checking its calibration date. Calibration intervals have been established for all torque tools used in the Navy. When a tool is calibrated by a qualified calibration activity at a shipyard, tender, or repair ship, a label showing the next calibration due date is attached to the handle. Check this date before you use a torque tool to ensure that it is not overdue for calibration.

You can find more information on torque values for different sizes and types of fasteners and correct tightening procedures in *Propulsion Gas Turbine Module LM2500*, Volume 2, Part 3, S9234-AD-MMO-050/LM2500, Chapter 8.1.

PLA ACTUATOR RIGGING TOOL SET

If the PLA actuator or main fuel control (MFC) of the gas turbine engine has been repaired or a card(s) has been replaced in the Free Standing Electronics Enclosure (FSEE), you may have to electronically rig the PLA actuator. Depending on your ship's policy, you and another GSE or a GSM will conduct this procedure.

The tools needed to rig the PLA actuator, other than a digital voltmeter (DVM) and a jeweler's screwdriver, are found in the PLA actuator rigging tool set. You will use the gauge and rig pins, number 4 and 6, as shown in

1. WHEN AN ADAPTER IS BEING USED WITH A TORQUE WRENCH, THE EFFECTIVE LENGTH OF THE WRENCH IS CHANGED. WHEN USING AN ADAPTER, THE TORQUE WHICH APPEARS ON THE DIAL OR GAGE OF THE WRENCH WILL BE DIFFERENT FROM THE ACTUAL AMOUNT OF TORQUE APPLIED TO THE NUT OR BOLT. THEREFORE, THE WRENCH MUST BE SET TO COMPENSATE FOR THE INCREASE OR DECREASE IN ACTUAL TORQUE COMPARED TO THE INDICATED TORQUE.
2. THE EFFECTIVE LENGTH OF THE ADAPTER MAY BE DETERMINED BY MEASURING FROM THE CENTER OF THE SOCKET OPENING TO THE CENTER OF THE WRENCH OPENING, PARALLEL TO THE CENTERLINE OF THE TORQUE WRENCH.
3. THE EFFECTIVE LENGTH OF THE TORQUE WRENCH MAY BE DIFFERENT FOR EACH TYPE OF WRENCH. THE EFFECTIVE LENGTH IS THE DISTANCE BETWEEN THE CENTERLINE OF THE DRIVE SQUARE AND THE CENTERLINE OF THE FORCE APPLIED AT THE HANDLE (CENTER OF HAND HOLD).
4. THE ADDITION OF THE EFFECTIVE LENGTH OF THE ADAPTER (**E**) IS DETERMINED BY THE POSITIONING OF THE ADAPTER ON THE WRENCH. WHEN THE ANGLE BETWEEN THE TORQUE WRENCH AND ADAPTER IS 90°, THE EFFECTIVE LENGTH OFTHE WRENCH IS UNCHANGED (SEE VIEW **B**). WHEN THE ANGLE IS GREATER THAN 90° (SEE VIEW **A**) THE EFFECTIVE LENGTH (**E**) OF THE ADAPTER WILL BE ADDED TO THE EFFECTIVE LENGTH (**L**) OF THE WRENCH. WHEN THE ANGLE IS LESS THAN 90° (SEE VIEW **B**) THE EFFECTIVE LENGTH (**E**) OF THE ADAPTER IS SUBTRACTED FROM THE EFFECTIVE LENGTH (**L**) OF THE WRENCH.
5. WHEN USING AN ADAPTER, THE INDICATED TORQUE MAY BE COMPUTED BY USING THE FOLLOWING FORMULA.

$$I = \frac{TL}{L \pm E}$$

T = DESIRED TORQUE
I = TORQUE INDICATED ON WRENCH
L - EFFECTIVE LENGTH OF TORQUE WRENCH
E - EFFECTIVE LENGTH OF ADAPTER

EXAMPLE OF VIEW **A**

I = ?
T 265 LB-IN.
L = 8.5 INCHES
E = 1.5 INCHES

STEP 1	STEP 2
$I = \frac{TL}{L+E}$	$I = \frac{265 \times 8.5}{8.5+1.5}$
STEP 3	**STEP 4**
$I = \frac{2252.5}{10}$	I = 225 LB-IN. (APPROXIMATE)

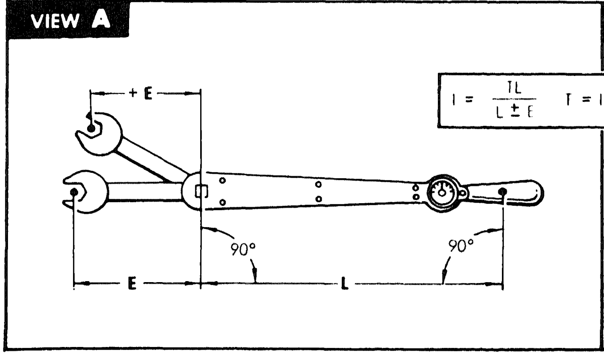
EXAMPLE OF VIEW **B**

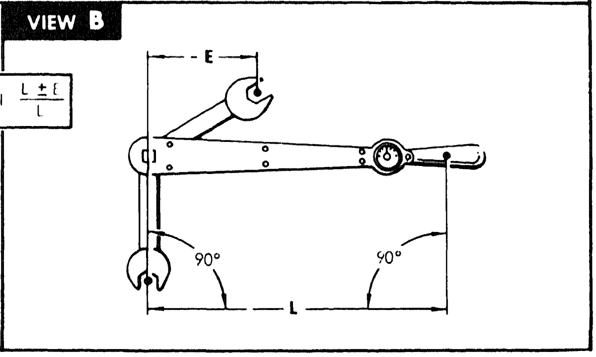
I = ?
T = 265 LB-IN.
L = 8.5 INCHES
E = 1.5 INCHES

STEP 1	STEP 2
$I = \frac{TL}{L-E}$	$I = \frac{265 \times 8.5}{8.5-1.5}$
STEP 3	**STEP 4**
$I = \frac{2252.5}{7}$	I = 322 LB-IN. (APPROXIMATE)

NOTE

IF EFFECTIVE LENGTH (**E**) OF THE ADAPTER IS 2 INCHES OR LESS AND THE ANGLE IS GREATER THAN 90° (SEE VIEW **A**), TORQUE TO LOWER HALF OF SPECIFIED TORQUE RANGE. IF EFFECTIVE LENGTH (**E**) OF THE ADAPTER IS 2 INCHES OR LESS AND THE ANGLE IS LESS THAN 90° (SEE VIEW **B**) TORQUE TO UPPER HALF OF SPECIFIED TORQUE RANGE





293.7

Figure 2-13.—Determining torque wrench correction factors.

figure 2-14. These pins are made of hardened carbon steel and have been machined for a precise fit. To maintain this precision fit, handle these pins carefully to avoid any damage which might result from carelessness. To perform this maintenance action, refer to the *Propulsion Gas Turbine Module LM2500* technical manual for details.

POWER TURBINE SPEED TRANSDUCER REPLACEMENT GAGE

If you should have to replace a power turbine (PT) speed transducer, then use the special clearance gage as shown in figure 2-15. The PT speed transducers operate in conjunction with a toothed gear which is attached to the PT rear shaft. The special gage unit is used to adjust the transducer for the air gap clearance between the transducer and the gear teeth. Detailed step-by-step procedures for this job are found in *Propulsion Gas Turbine, Trouble Isolation*, Volume 2, Part 3, NAVSEA S9234-AD-MMO-050/LM2500.

GAS TURBINE GENERATOR SET SPEED SENSOR PICKUP DEPTH GAGE

The speed sensor pickup is located on the power takeoff (PTO) assembly of the Gas Turbine Generator Set (GTGS). The speed sensor pickup is a magnetic pickup, situated over the exciter wheel teeth. The rotation of the exciter teeth on the PTO shaft passing the speed sensor pickup produces electrical impulses.

If, for any reason, you have to replace the speed sensor pickup, then use a special depth gage in the procedure. The depth gage is installed in the torquemeter's housing pickup mounting hole. As the gage is held firmly against the shaft exciter teeth, a feeler gage is used to measure the gage-to-pickup mounting flange clearance. This measurement will determine the amount of shims required between the sensor and the mounting flange. The shims will provide the required air gap between the exciter teeth and the speed sensor tip. Detailed instructions for this procedure are found in *Model 104 Gas Turbine Generator Set, Trouble Isolation*, Volume 2, Part 3, NAVSEA S9234-BC-MMO-030/MOD 104 GTGS.

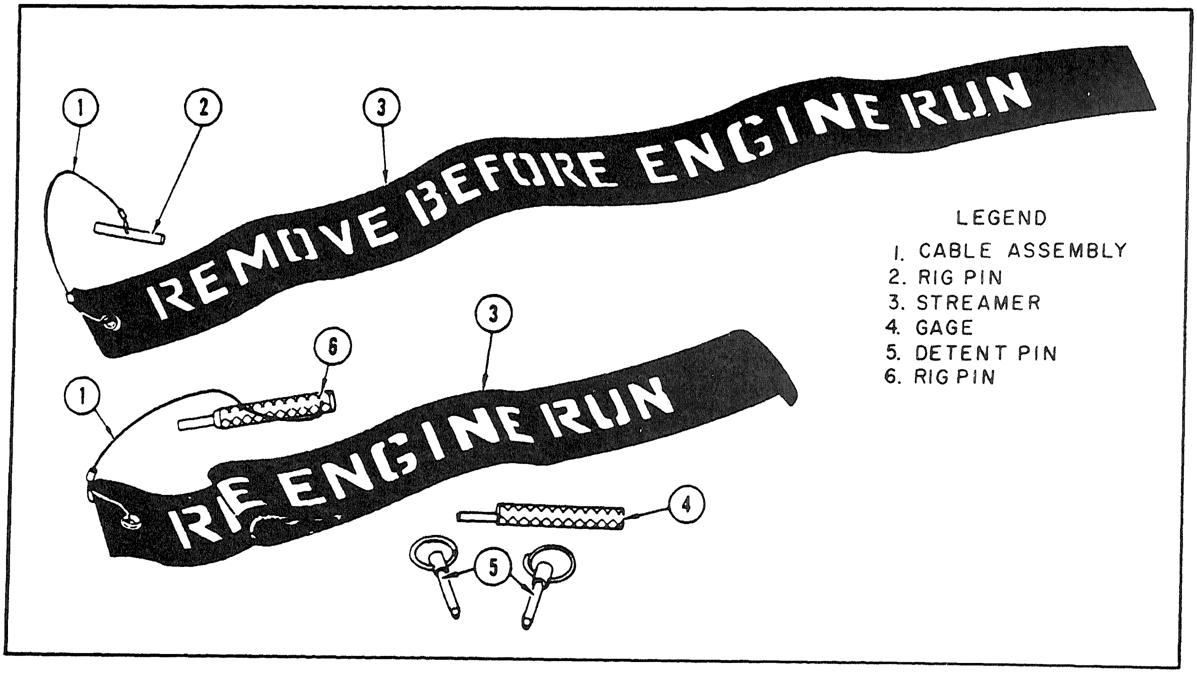


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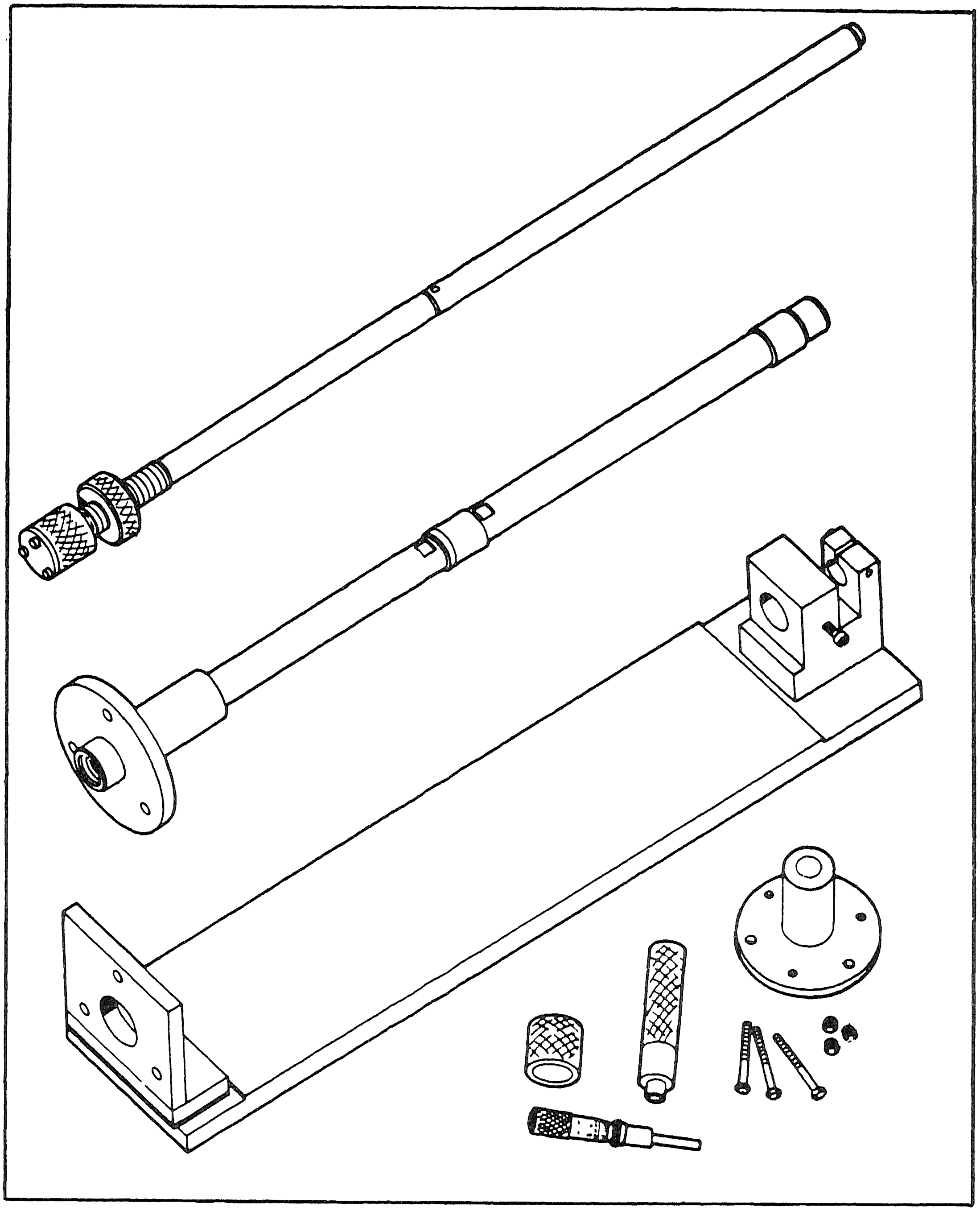
Figure 2-14.—Tool set, PLA actuator rigging.



293.9

Figure 2-15.—Overspeed transducer clearance gage.

FASTENERS

While performing maintenance procedures on your equipment, you will find various types of fasteners. Standard nuts, bolts, washers, wingnuts, and screws are familiar ones. Two types which you may not be familiar with are discussed in this section. They are the Camloc and locknut fasteners.

CAMLOC FASTENERS

Camloc fasteners are made in a variety of styles and designs. They are generally found on electrical controller doors and the gas turbine generator (GTG) local operating panel. Regardless of the particular style or shape, the Camloc fastener consists of a stud assembly, receptacle, and a grommet (figure 2-16).

The stud assembly consists of a stud, a cross pin, spring, and spring cup. The assembly can be quickly inserted into the grommet by compressing the spring. Once installed in the grommet, the stud assembly cannot be removed unless the spring is again compressed.

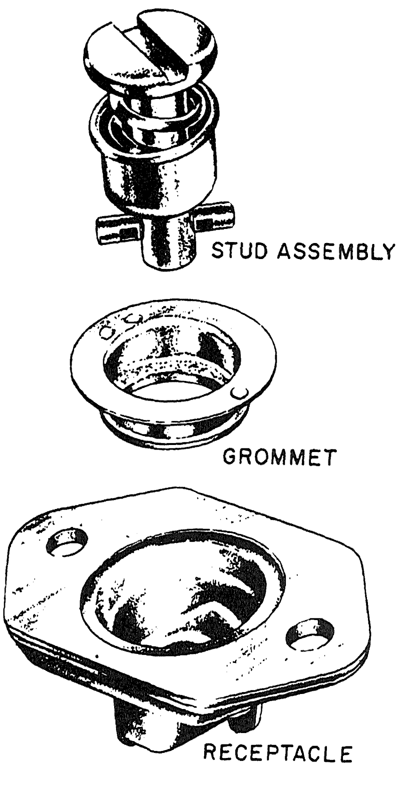


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Figure 2-16.—Camloc fastener.

The grommet is a flanged sheet-metal ring made to fit into a hole in the access door or panel. It is ribbed and can be pressed or dimpled into place.

The receptacle consists of a metal forging mounted in a stamped sheet metal. It is riveted to the access opening frame attached to the structure or equipment.

A quarter turn clockwise of the stud screw locks the cross pin into the grooved receptacle. Conversely, a counterclockwise rotation releases the connection between the stud assembly and the receptacle.

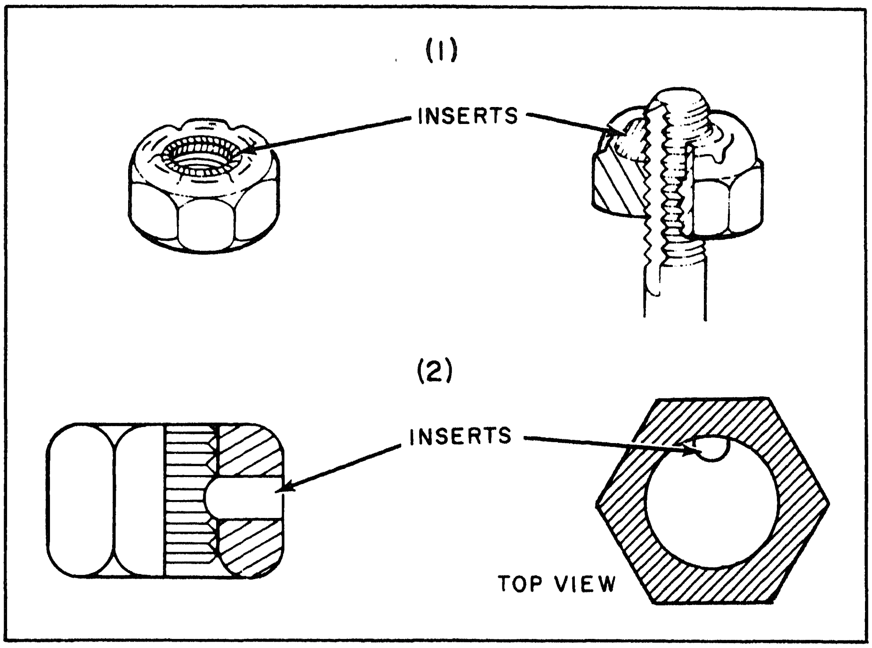
LOCKNUT FASTENERS

Locknuts, commonly referred to as self-locking, are used where it is essential that the nut does not come loose. Various types of locknuts are used throughout the Navy. Two types which you will use are the annular plastic ring nuts and nylon insert nuts.

The plastic insert (figure 2-17, item 1) in the ring nut is deformed when the bolt is installed. The resilient plastic material is forced to assume the shape of the mating threads, creating large frictional forces.

Nylon insert nuts (figure 2-17, item 2) have plastic plugs which do not extend completely around the threads. The plastic plugs tend to force the nut to the side, cocking it slightly. This produces frictional forces on one side of the bolt thread. Although the plastic plug will lock without seating, proper torque applied to the nut stretches the bolt, creating clamping forces that add to the locking abilities of the nut.

Before reusing the plastic ring or nylon insert nuts, check the inserts. If they are worn or torn, discard the nut and use a new one. If you can install the nut to the point where the bolt threads pass the insert without a wrench, discard it and use a new nut.



293.10

Figure 2-17.—Locknuts. (1) Plastic ring nut (2) Nylon insert nut.

TEST EQUIPMENT

As a GSE, you will use a variety of test equipment to help troubleshoot and repair the newer, more sophisticated electrical/electronic gear. This section will acquaint you with a useful and logical troubleshooting method. You will learn about some of the test equipment that you may operate when troubleshooting and repairing electrical/electronic gear.

TROUBLESHOOTING

Troubleshooting is the art of locating the problem. Like any art, it requires talent and training before it is developed into truly great work. Over the years GSEs have developed specific theories as to how to go about their art. Since they are passed on to you free of charge, it will stand you well to use them.

The first step in logical troubleshooting is to recognize a normal condition; in other words, to determine that everything is working properly. For example, the second hand on your watch is going through 360 degrees in a clockwise direction every minute. The chances are pretty good that the second hand is working properly. If, however, you had never seen a watch before, you would have no idea if the second hand was working properly. When you are dealing with the different sensors or various parameters of the gas turbine engine or the generators, the problem of recognizing normal conditions is far more complicated. You may need an explanation from a senior or from the manufacturer's technical manual to understand normal equipment functioning. The point is you must recognize the normal condition of equipment before you can consider its maintenance. Determining a malfunction is the second logical step in the art of troubleshooting. It is the ability to recognize when a malfunction is occurring, is about to occur, or has occurred. Then you can assume that the equipment is not functioning normally, or will not function normally for much longer.

Picture again the watch, but this time the second hand has stopped. A malfunction has occurred at some previous time. Perhaps someone has forgotten to wind the watch. Since you recognize the normal condition for the second

hand, you are aware that a malfunction has occurred. If, however, when you looked at the watch you noted that the second hand was moving at a rate of 10 degrees in a 1-minute period, you could safely assume that a malfunction was occurring. The third situation occurs when the watch is running at the proper rate but you note a grinding sound from somewhere in its interior. You could then assume with some reliability that a malfunction was about to occur. Again, the criterion of step one remains true: you have to recognize a normal condition before you can determine a malfunction.

Step three in logical troubleshooting falls right in place once you are sure of the malfunction's existence. Collect all available data regarding the malfunction in order to find the symptoms. Is the unit running at all? Is it within the normal temperature and pressure range? Has this malfunction occurred before? Is the malfunction occurring only during a specific set of circumstances? Is the unit noisy?—Out of calibration?—Over or under design limits? Don't overlook anything. The smallest unit of information that you collect may in the final analysis be the solution to the problem.

Now that you have collected all of the symptoms of the malfunctions, the next step is to list the possible causes. Many manufacturers' technical manuals list the "probable cause" in the corrective maintenance sections. Discussing the malfunction with another GSE may result in your realizing several causes that were not apparent to you.

Now you are armed with a complete set of symptoms and the probable causes of these symptoms. You, as the troubleshooter, can now begin the painstaking checks which will ultimately lead to isolation of the malfunction. To sectionalize the trouble means to track it down into one specific area of a piece of equipment. You do this by going over the energizing procedure slowly and determining when the trouble first appears. You may use a troubleshooter's chart in the manufacturer's technical manual or the probable causes that you have listed.

Once you have determined which section of a system is malfunctioning, in a matter of time the defective component(s) can be isolated and repaired. During this final step of troubleshooting, it is most important that you, the GSE, use every method of isolation. You can determine an open resistor through the use of a meter; however, you waste time if you do not note that the component is discolored when you originally open the chassis for inspection. In troubleshooting the GSE must be attentive—look, listen, smell, and feel—to ensure good, quick, trouble isolation.

Further information discussing troubleshooting techniques not covered in this section may be obtained from Navy Electricity and Electronics Training Series (NEETS), Module 16, *Introduction to Test Equipment*, NAVEDTRA 172-16-00-84.

PRECAUTIONS

Basic electrical indicating instruments receive extensive coverage in *Basic Electronics*, NAVPERS 10087 (revised). The information here is a reminder of certain specific precautions which are applicable to them and to all test equipment. The delicate mechanisms of most test equipment require that you take pains to avoid rough handling. You should prevent moisture and dust or fine magnetic particles from entering the case. Another harmful condition is the subjection of the unit to an input signal of a magnitude greater than the range which is selected on the input scale. Also, the use of the instrument in close proximity of strong magnetic fields or subjecting the meter movement to high potential sources while attempting to calibrate or service it could damage it. In summary, you should understand the specific piece of equipment that you are using and the circuit upon which you are using it.

RESISTANCE BOXES

At one time or another while performing maintenance actions, you will use a resistance box such as the type shown in figure 2-18. These boxes, generally oblong in shape, contain variable resistors. On top of the boxes you will see either four, five, or six rotary switches depending on the type of box used. Each switch will have the numbers 0 through 9 on it. Below each switch you will see a number known as the multiplier. Three terminals are located on the right-hand side of the box to connect it with the circuit(s). Some of the boxes may also have a decimal point, such as between switches (3) and (4) in figure 2-18.

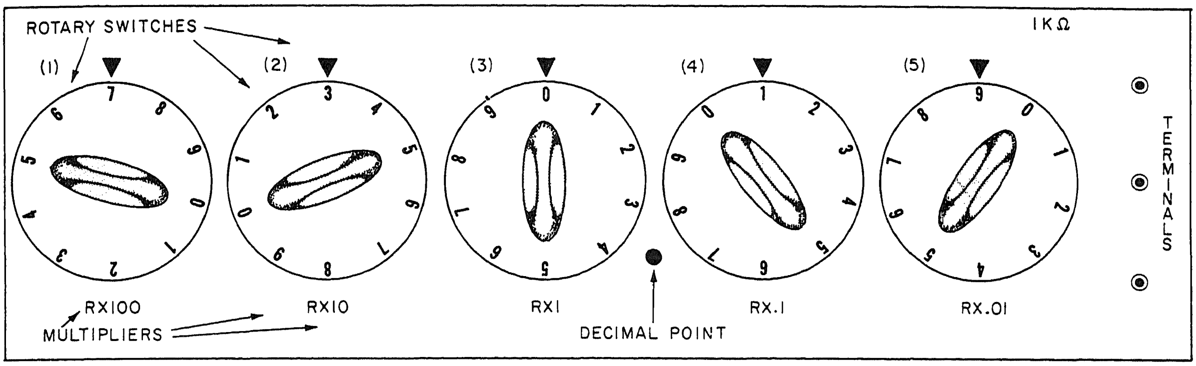


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Figure 2-18.—1 K-ohm decade resistance box.

The resistance boxes have been designated with different ohmic values. Printed on the top of the box you will find the upper limit. For example, a 1 kilohm (kΩ) box will range from .01 to 999.99 ohms, a 1 megohm (MΩ) box will range from 1 to 999,999 ohms.

Each rotary switch on the box controls its own variable resistor. These resistors are arranged so that each resistor's value can be collectively added to each other. Using the figure and reading the switches from left to right; (1) is in the hundreds place, (2) is tens, (3) is ones, (4) is tenths, and (5) is hundredths. To determine the value of a resistor, such as (2) in the figure, read the dial setting which is 3, and its multiplier which is R × 10. This becomes 3R × 10 or 3 ohms × 10. Therefore, the value of resistor (2) is 30 ohms at this setting. All of the other resistors are calculated in the same manner. The values of each resistor are then added together to get the total resistance of the box. What is the total resistance of the box in figure 2-18? If you figured it out correctly, it would be 730.19 ohms.

You will use these resistance boxes when checking the calibrations of equipment such as $P_{t5.4}$ sensors and various transducers. Also, if the value of a resistor is unknown, the box may be connected in series with the resistor. Since you know the value of the box, you can then determine the value of the resistor.

POWER SUPPLIES

The power supplies discussed in this section are NOT the same power supplies located in your consoles. These power supplies are used when you are performing maintenance or checking equipment operation. The type you will normally use ranges from 0 to 50 V d.c. This is more than adequate for the majority of your work.

These power supplies are simple and easy to use. On the front of the power supplies you will see the output controls, a voltage meter, and the terminal connections.

When using the power supplies, make sure you follow all safety precautions. Refer to the manufacturer's technical manual for the proper operating procedures. To avoid damaging the equipment you are working on, know its limits and do not exceed them. When making connections, be sure you observe proper polarity.

PRESSURE TRANSDUCER CALIBRATION KIT

You will use the pressure transducer calibration kit when performing maintenance on the various pressure transducers. The kit consists of three suitcase-type containers and a dual diaphragm vacuum pump.

The absolute pressure calibration unit is in one container. You will use this unit when calibrating the absolute pressure transducers. The unit has two panel-mounted gauges, a high pressure regulator, a vacuum/pressure regulator, and a selector valve. The three connection ports are for

high pressure supply, regulated pressure out, and vacuum source.

The gauge pressure and differential pressure calibration unit is in another container. It is used when you calibrate the gauge pressure and differential pressure transducers. The unit has three panel-mounted gauges, a high pressure regulator, and a selector valve.

The third container provides storage for the multimeter and leads, the nitrogen bottle regulator, and the hose assemblies. The nitrogen bottle is separate and does NOT come with the kit.

Before you calibrate any of the pressure transducers, be sure the gauges on the calibration units do not require calibrating. Refer to *Propulsion Gas Turbine Module LM2500, Trouble Isolation*, Volume 2, Part 3, S9234-AD-MMO-050/LM2500 for detailed procedures.

LM2500 THERMOCOUPLE SIMULATOR/CALIBRATOR

The thermocouple simulator/calibrator is used to test and adjust the $T_{5.4}$ signal conditioner and detectors. The thermocouples surround the turbine midframe and the signal conditioner is located under the base/enclosure plate. The simulator/calibrator is connected to the gas turbine inside the enclosure near the 4 o'clock position on the turbine midframe. The adjustment procedures are performed at the FSEE.

This procedure can best be accomplished if two people perform the test/alignment and use headphones to communicate with each other. One person adjusts the simulator/calibrator for the required inputs and the other person makes the necessary adjustments at the FSEE. Detailed instructions for this procedure are found in *Propulsion Gas Turbine Module LM2500, Trouble Isolation*, Volume 2, Part 3, NAVSEA S9234-AD-MMO-050/LM2500.

STC 4325 SPEED-TEMP SIMULATOR

The speed-temp simulator is an accessory box that simulates GTG speed and temperature. The simulator outputs a d.c. voltage to simulate temperature and a square wave frequency to simulate engine speed.

There are three hookups you must make in order to use the box. The first, for simulating speed, is connected into the cannon plug that attaches to the PTO speed pickup. It is located on top of the PTO shaft in the reduction gear section of the module. The second connection is made in the local operating control panel (LOCOP) to supply 24 V d.c. to the simulator. The third, for simulating GT inlet temperature, is made on the engine at the thermocouple block.

You will use the simulator when testing, troubleshooting, or calibrating the LOCOP. This allows you to test the LOCOP start/stop circuitry without running the engine or exceeding design limits of the GTGS. It also allows you the opportunity to check the LOCOP meters against test equipment that is calibrated to higher standards. A frequency counter and a digital thermometer are used to measure the exact output of the simulator. This output is used to set the LOCOP panel meters.

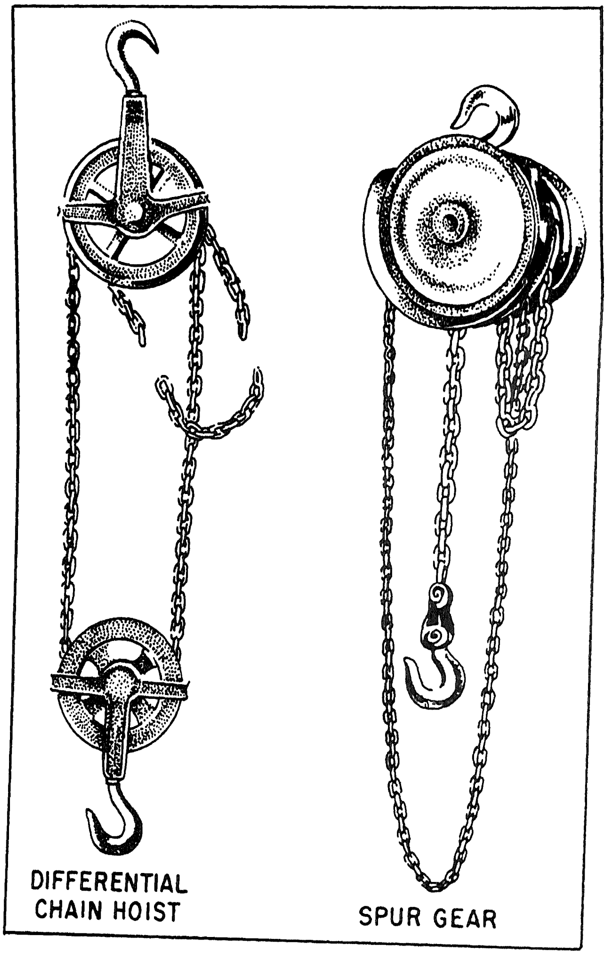

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Figure 2-19.—Chain hoists.

You can find the procedures for adjusting and testing the LOCOP using the simulator in *Model 104 Gas Turbine Generator Set, Trouble Isolation*, Volume 2, Part 2, NAVSEA S9234-BC-MMO-030/MOD 104 GTGS.

HOISTING AND LIFTING DEVICES

When performing maintenance, you may have to move or lift some of the heavy equipment or components. You can use various devices to accomplish this. The selection of the proper device depends on many factors, such as the equipment to be moved and the available work space. A working knowledge of the following devices will aid you in selecting the right device.

CHAIN HOISTS

Chain hoists (chain falls) provide an easy and efficient method for hoisting loads by hand. The advantages of chain hoists are that one person can raise a load of several tons, and the load can remain stationary without being secured. A chain hoist permits small movements, accurate adjustments of height, and gentle handling of loads. For these reasons they are particularly useful in hoisting motors or parts which must be precisely aligned with other parts. Two of the most common types used for vertical hoisting operations are the spur gear hoist and the differential chain hoist (figure 2-19).

The spur gear hoist is used for operations that require frequent use of a hoist and where few personnel are available to operate it. The spur gear hoist is about 85-percent efficient. In other words, about 85 percent of the energy that you exert is converted into useful work for lifting the load. The remaining 15 percent of the energy is spent in overcoming friction in the gears, bearings, and chains.

The differential chain hoist is suitable for light loads and where only occasional use of the hoist is involved. This hoist is only about 35-percent efficient.

The mechanical advantages of chain hoists vary from 5 to 250, depending on their rated capacities, which range from 1/2 ton to 40 tons. The load capacity of a chain hoist is stamped on the shell of the upper block.

The lower hook is usually the weakest part in the assembly of a chain hoist. This is intended as a safety measure so that the hook will start to spread open if overloaded. Thus, you must closely watch the hook to detect any sign of overloading in time to prevent damage.

Before using a chain hoist, inspect it to ensure safe operation. Replace a hook that shows signs of spreading or excessive wear. If links in the chain are distorted, the chain hoist has probably been overloaded. In any case, make sure the hoist is in good repair before attempting to lift a load.

PUSH-PULL HYDRAULIC JACK

A push-pull hydraulic jack, commonly called a port-a-power, consists of a pump and ram connected by a flexible hose (figure 2-20). Jacks of

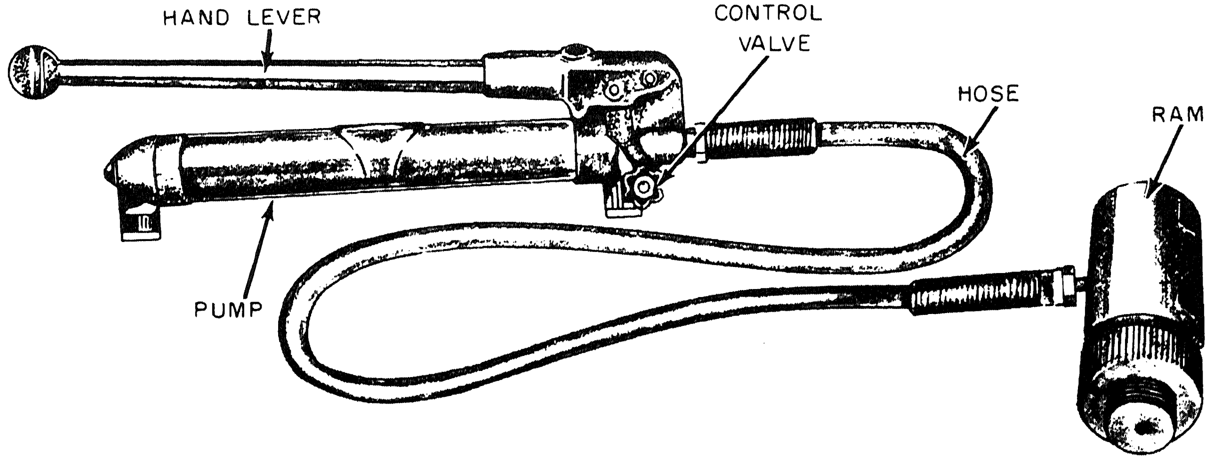

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Figure 2-20.—Push-pull jack.

this type are rated at 2-, 7-, 20-, 30-, and 100-ton capacities and have diversified applications. These jacks are furnished with an assortment of attachments. These attachments enable you to perform countless pushing, pulling, lifting, pressing, bending, spreading, and clamping operations. The pump is hand operated. A flexible hydraulic hose allows you to operate the ram in any desired position and from a safe distance. The ram can be retracted automatically by turning a single control valve.

When using the port-a-power to raise a part, make certain no one is under the part. Keep fingers away from all moving parts. Be sure to place blocking or other supports under the part when it is raised to the desired height to prevent it from dropping if the jack fails. Before using a hydraulic jack of any type, make sure it is filled with fluid and has no apparent leaks.

HAND-OPERATED RATCHET LEVER HOISTS

Hand-operated ratchet lever hoists (figure 2-21), more commonly called come-a-longs, are similar to the chain fall. The main difference is that the lower hook moves as you operate the ratchet handle. The direction of movement is changed by a lever on the side of the unit or in the handle.

Compared to the chain fall, the come-a-long is smaller because of the size difference of the top portion of the units. The come-a-long is used in maintenance as is the chain fall; however, it is NOT as good when using it for the alignment of parts. The reason for this is that the ratchet mechanism does not allow for minimal movements as does the chain fall.

CRANES

As a general rule, the cranes you will use will be located pierside. The crane is used when equipment must be moved to a pierside facility, such as a Shore Intermediate Maintenance Activity (SIMA), for overhaul. Ship's personnel will generally move any equipment to the main deck of your ship, and then off-load it by crane. Obviously, when removing a gas turbine engine,

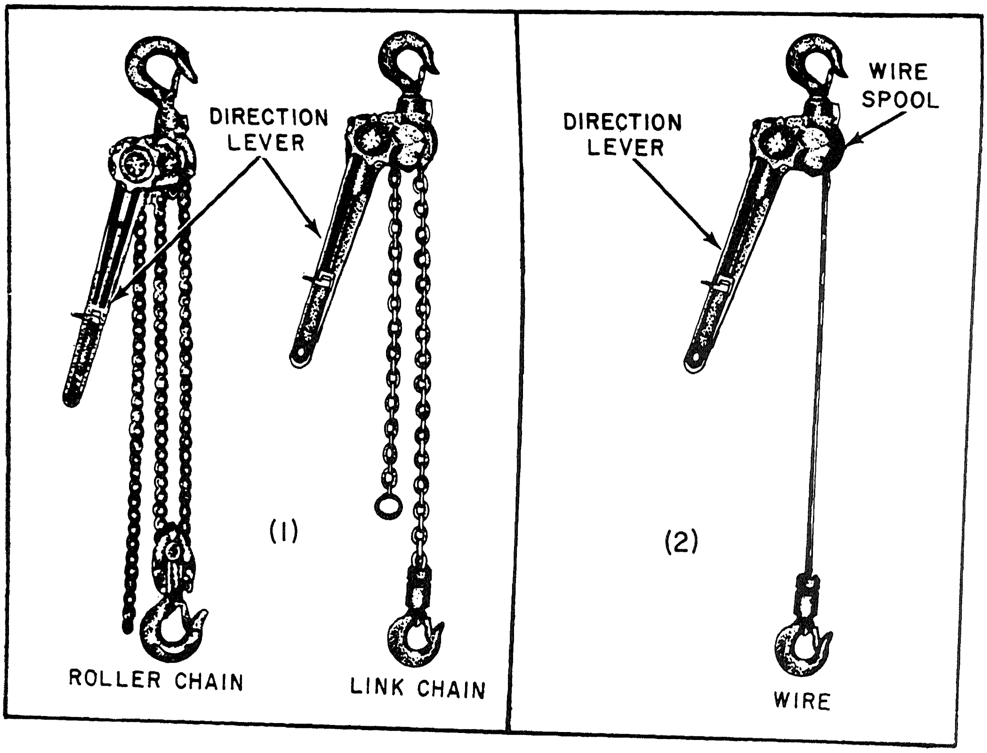

Figure 2-21.—Hand-operated rachet lever hoists. (1) Chains (2) wire. 293.12

ship's personnel will not move the engine topside. In this situation, the crane will drop its hook down the inlet plenum of the gas turbine engine. Special rails will be installed in the inlet plenum to facilitate the removal.

NOTE: When using any of the hoisting and lifting devices discussed in the above section, ensure they are in good working order prior to use. All chain and hand-operated ratchet lever hoists must be lead tested and tagged. You must ensure the tag is on the hoist and it is not overdue for testing. When using any of the various hoists, you must use a safety line or wire to secure the hooks. This will aid in preventing the hooks from coming loose while attached to the item being moved. If beam clamps, C-clamps, or wire straps are used, make sure they are secured properly and in good condition before attaching the lifting devices to them. When you use beams or pad eyes to anchor the hoists, you must ensure they will withstand the weight of the item being moved.

SUMMARY

This chapter introduced you to some of the tools, test equipment, and devices you will use during maintenance or while performing operational checks. Not all the equipment was covered in this chapter. The sources of information you were referred to will help you learn the required information.

After studying the referral sources, you may still have unanswered questions. The referral sources will direct you where to find the answers.

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CHAPTER 3

INDICATING INSTRUMENTS

Centralized operation of gas turbine propulsion plants rely on accurate readings from remote sensors. One of your jobs, as a GSE, is to maintain these sensors in a high state of reliability. Many remote devices are used in the gas turbine propulsion plant to give watch standers accurate information. This data allows the watch personnel to take correct action in the event of a casualty. Faulty sensors, if not promptly repaired, could allow problems to go unnoticed and lead to major casualties.

This chapter describes the different types of sensors that you could come into contact with while maintaining gas turbine propulsion systems. Sensors are devices that allow you to observe a condition without being at the location of the device. The conditions that you may observe as an operator are many. They include pressure, temperature, liquid level, speed, vibration level, or electrical values such as volts or amperes. You, as a GSE, will see these indications are actually just changes of resistance, current, or voltage. Your job is to ensure that the sensor's output gives the operator a correct reading in the entire range of the sensor. The procedures described in this rate training manual (RTM) are for representative-type devices. When you repair or calibrate sensors, make sure you follow the instructions given in the manufacturers' technical manuals. Sometimes you may have to use other reference materials or technical information not provided by the manufacturer.

After reading this chapter, you should be able to describe some of the sensing devices used to provide indications. These include sensing, pressure, and temperature devices and the operation of each. You should also be able to identify and describe the various electrical indicating instruments used on the engineering consoles.

TEMPERATURE SENSORS

The most common sensor you will find in a gas turbine plant is the temperature sensor. Monitoring temperatures of liquids and gases usually provides the first indication of a problem. For example, the first sign of a failed main reduction gear (MRG) bearing is the high outlet temperature of the bearing oil. If you do not have an accurate temperature of the bearing oil, you may overheat the bearing causing it to seize. This could cause severe damage to an expensive MRG. You must act promptly to repair any malfunctioning temperature sensor.

You will use many types of temperature sensing devices. These include types which provide a variable output, used for meters, digital readouts, and logging functions. They also include the fixed output devices such as temperature switches, which have a single preset value. In the following pages we will discuss each type of sensor and explain how you can use their outputs. We will also discuss the calibrations required for several of these sensors.

RESISTANCE TEMPERATURE DETECTORS

The resistance temperature detector (RTD) operates on the principle that electrical resistance changes in a predictable manner with temperature changes. The element of an RTD is made of nickel, copper, or platinum. Nickel and copper are used for temperatures of 600°F or lower. Platinum elements are used for temperatures of

600 °F or greater. Figure 3-1 shows two typical types of RTDs.

You will usually find RTDs mounted in thermowells which will protect the sensor from the medium it is sensing. This also lets you change the RTD without securing the system in which it is mounted. This makes your maintenance easier and less messy.

As temperature increases around an RTD, the corresponding resistance will also increase at a proportional value. The temperature applied to an RTD, if known, will give you a known resistance value. You can find these resistance values listed in tables in the manufacturers' technical manuals. Normally, only a few resistance values are given. To test the RTD, you will have to heat it to a specific temperature. At this temperature the resistance of the RTD should be at the resistance shown in the table. The most common method of heating an RTD is to use a pan of hot water and a calibrated thermometer.

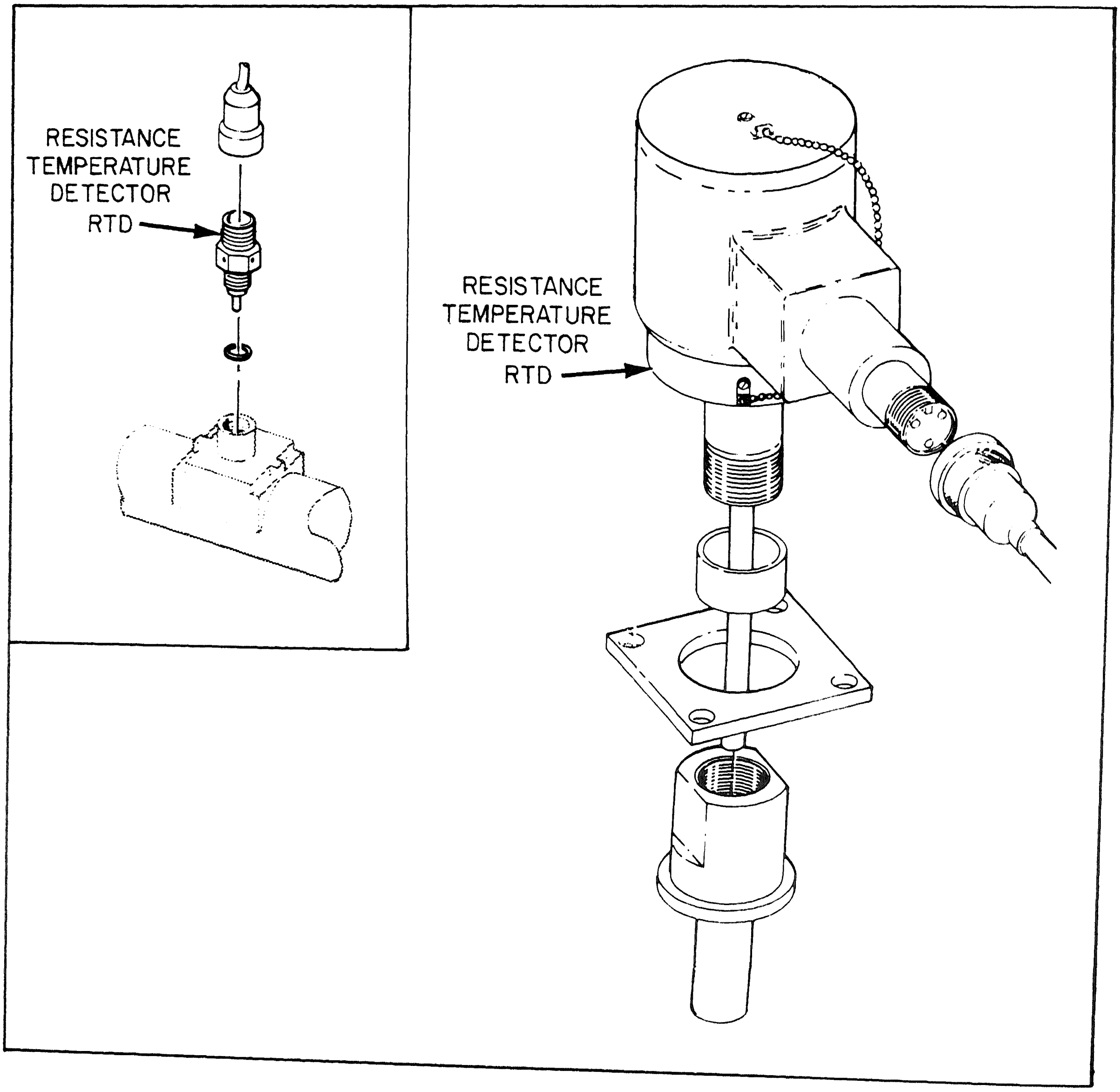

Figure 3-1.—Two typical types of resistance temperature detectors (RTD). 293.13

Some newer ships and repair activities test RTDs using a thermobulb tester. This method is more accurate and easier to use. For specific instructions, refer to the manufacturers' technical manuals supplied with the equipment.

The most common fault you will find with an RTD will be either a short circuit or an open circuit. You can quickly diagnose these faults by using digital display readings or data log printouts. By observing the reading or the printout, you may find that the indication is either zero or a very low value. A malfunction of this type means there is a short circuit in either the RTD or its associated wiring. A very high reading, such as 300 °F on a 0 °F to 300 °F RTD, could indicate an open circuit. You should compare these readings to local thermometers. This ensures that no abnormal conditions exist within the equipment that the RTD serves.

If an RTD is faulty, you should replace it at the earliest opportunity. Internal repairs cannot be made to RTDs at the shipboard level. Until you can replace the faulty RTD, you should inform the watch standers that the RTD is unreliable. The engine room watch standers should periodically take local readings to ensure the equipment is operating normally.

RESISTANCE TEMPERATURE ELEMENTS

Resistance temperature elements (RTEs) are the most common type of temperature sensor that you will find in gas turbine propulsion plants. The RTEs operate on the same principle as the RTDs. As temperature of the sensor increases, the resistance of the RTE also increases at a proportional value. All RTEs that you encounter have a platinum element and have an electrical resistance of 100 ohms at a temperature of 32 °F. Four different temperature ranges of RTEs are commonly used, but you will find that the probe size varies. The four ranges and their probe sizes are:

TEMPERATURE RANGE (Degrees Fahrenheit)	RTE PROBE LENGTH (Inches)
−20° to +150°	6
0° to +400°	2, 4, 10
0° to +1000°	2
−60° to +500°	6

You may find some RTEs that are connected to remote mounted signal conditioning modules. These modules convert the ohmic value of the RTE to an output range of 4 to 20 milliamperes (mA) direct current (d.c.). However, most RTEs read their value directly into the propulsion electronics as an ohmic value.

The 0° to +400 °F and the −60° to +500 °F range RTEs are commonly mounted in a thermowell. The thermowell is used to protect the sensor from physical damage by the medium being measured. Since you can change the RTE without securing the equipment it serves, this also simplifies maintenance.

THERMOCOUPLES

Thermocouple sensors are used to monitor LM2500 power turbine inlet temperature ($T_{5.4}$) and Allison 501-K17 turbine inlet temperature (TIT). Although each engine uses a different type of thermocouple, the theory of operation is the same. These sensors work on the principle that when two dissimilar metals are fused together at a junction by heat, a small voltage is produced. The magnitude of this voltage is directly proportional to the $T_{5.4}$ or TIT.

Figure 3-2 shows you the two different types of thermocouples. You should note that although they are physically different, their operation

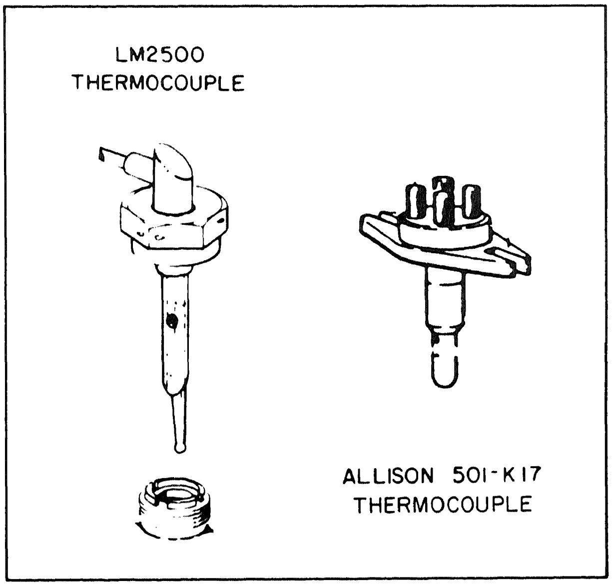

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Figure 3-2.—Types of thermocouples.

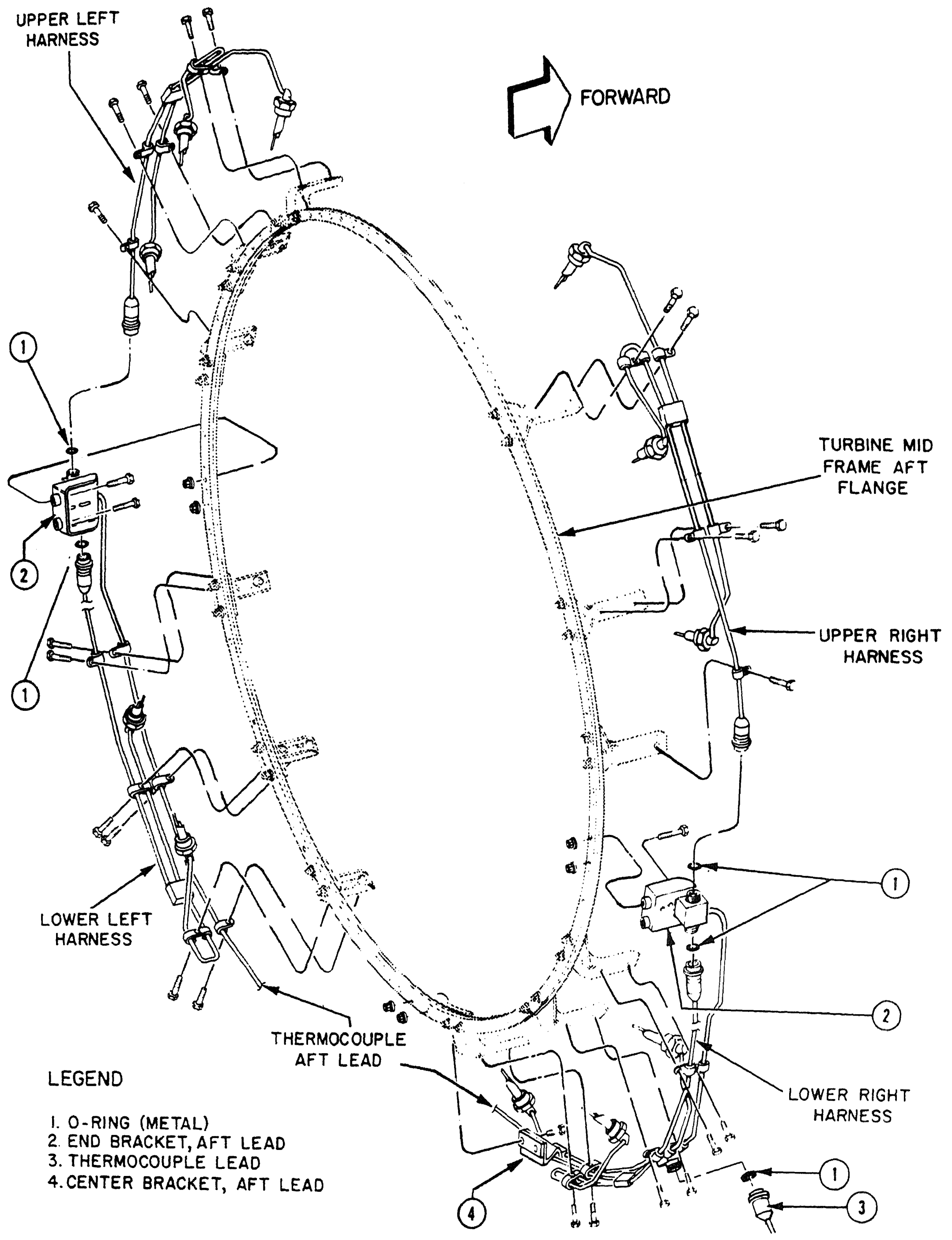

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Figure 3-3.—LM2500 thermocouple harness.

ıe same. Both types of thermocouples are ıposed of the metals Chromel and Alumel.

2500 Thermocouples

Γhere are eleven thermocouples used on the 2500 to monitor $T_{5.4}$. Individual thermo- ɔles cannot be replaced though, as they are nged into four groups. These groups, or ıesses, are the components you must change ou have a faulty thermocouple. The four ıesses are shown in figure 3-3. You should ; that the two upper harnesses and the lower t harness each contains three thermocouples. lower left harness has only two thermo- ɔles. Be very careful when you replace a ıess. Take care not to damage a probe or bend ıarness. For more information on replacement hermocouple harnesses refer to the *Propul- Gas Turbine Module* LM2500, Volume 2, : 3, NAVSEA S9234-AD-MMO-050.

ʟM2500 THERMOCOUPLE SIGNAL CON- IONING.—The output voltage of the 2500 thermocouples is a relatively low level. nput this into the propulsion electronics, the al must be processed. A signal conditioner ʼerts this small input voltage to an output on range of 4 to 20 mA d.c. The output of a ɔte signal conditioner is then sent to the free signal conditioning enclosure (S/CE) on the DD-963 and CG-47 classes. The signal is conditioned in the free standing electronic enclosure (FSEE) on the FFG-7 class. It is then converted to a 0 to 10 V d.c. signal for use in the propulsion electronics.

TROUBLESHOOTING LM2500 THERMOCOUPLES.—You will find the procedures to troubleshoot the LM2500 thermocouples in the LM2500 technical manual series. Ensure you follow the step-by-step procedures to properly isolate the faulty harness. You usually troubleshoot thermocouples by using an ohmmeter. If the readings you take are not in tolerance, you will have to replace the thermocouple harness section that is faulty.

Allison 501-K17 Thermocouples

Eighteen dual-element, Chromel-Alumel thermocouples are used on the Allison 501-K17 engine to monitor TIT. Unlike the thermocouples of the LM2500, you can change these thermocouples individually. Each of these sensors has two independent elements which allow two sampling circuits per thermocouple. Only one circuit is used for monitoring TIT; the other circuit is not monitored. Figure 3-4 illustrates the thermocouple installation on the Allison engine.

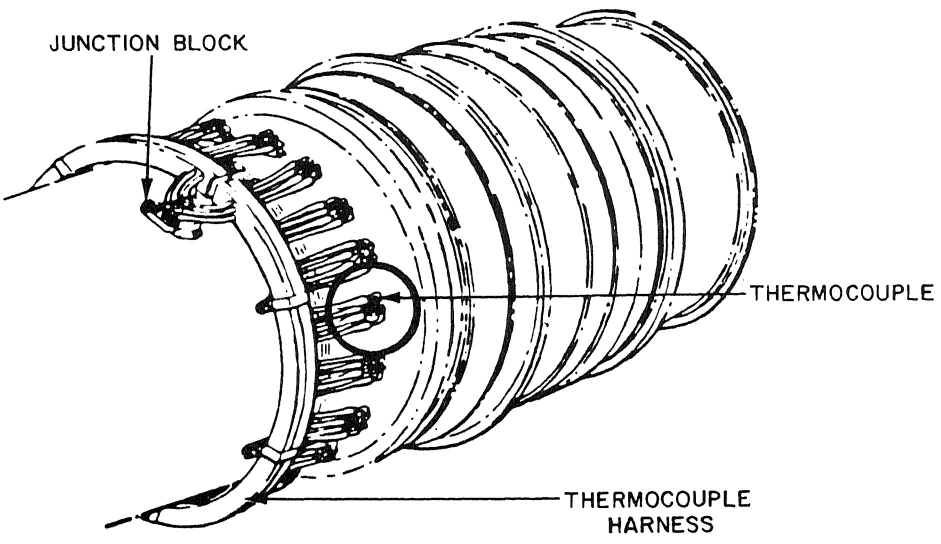

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Figure 3-4.—Gas turbine generator thermocouple harness.

The interconnecting harness for the thermocouples, as shown in figure 3-4, mounts on the outer combustion case forward of the thermocouples. This harness includes four separate leads for each of the eighteen sensors. There are two separate electrical circuits maintained. The harness is made in two halves: a right-hand side and a left-hand side. Note in figure 3-4 that the harness is split near the thermocouple junction. This allows you to easily remove the wiring without major engine disassembly. The electrical signals from the thermocouples are averaged within the harness. The output of the thermocouple harness is sent to the LOCOP for signal conditioning. We will discuss the operation of the LOCOP in chapter 8.

A faulty thermocouple will give you a false TIT reading. TIT is a basic parameter for the liquid fuel valve (LFV) adjustment. Therefore, a faulty sensor would result in an incorrectly adjusted LFV. You should check the continuity of the thermocouples if you suspect the TIT reading is incorrect. Also check it if you suspect the liquid fuel valve is out of adjustment. The thermocouple continuity is read using an ohmmeter. Each thermocouple has four terminals, but only two are used for monitoring TIT. Find the two terminals that are used for TIT and read the resistance between them. If the reading on a thermocouple is over 10 ohms you must replace that sensor. You will find instruction on thermocouple replacement in the *Model 104 Gas Turbine Generator Set*, NAVSEA S9234-BC-MMO-030.

MODULE AND CONSOLE TEMPERATURE SENSORS

Some of the temperature sensors you will find are used to monitor the ambient air temperature in an enclosed area. These indications alert personnel if the air temperature surrounding a piece of equipment is above the normal operational level. A few enclosed areas that we will discuss are modules, such as gas turbine enclosures, power supplies, and consoles. Overtemperature in these areas could be indications of equipment overheating, cooling system failures, or fires. To prevent equipment damage, you should immediately investigate high temperature conditions in any enclosed area.

Module Temperature Sensors

Gas turbine modules (GTMs) have two types of sensors which are used to monitor the enclosure temperature. One sensor is used to display the module temperature; there are two others used to detect fires. The module temperature sensor used for monitoring the enclosure temperature is an RTD. It is mounted on the barrier wall below the compressor. The temperature sensors used on the LM2500 for fire detection are also RTDs. These two sensors are mounted on the overhead of the module. Their output is inputted into the FSEE. This fire detector RTD signal is not outputted to the propulsion electronics, except as a fire signal.

Console Temperature Sensors

The temperature sensors used in consoles and power supplies are used to inform you that the enclosures are overheated. Many types of sensors are used. We have not covered all of them in this manual. If you need more information on these temperature switches, consult the manufacturers' technical manuals for your equipment.

TEMPERATURE SWITCHES (DETROIT-TYPE)

Temperature switches (Detroit-type) operate from temperature changes occurring in an

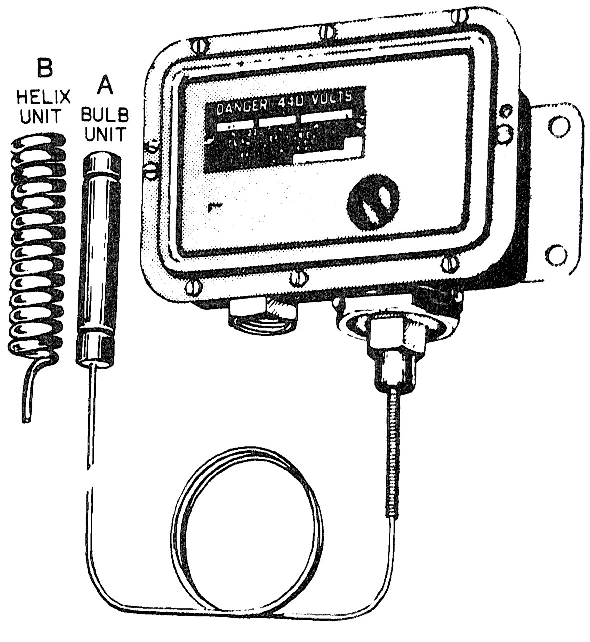

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Figure 3-5.—Temperature switch with two types of sensing elements (a) bulb unit (b) helix unit.

enclosure, or in the air surrounding the temperature sensing element. The operation of the Detroit-type temperature switch is not much different than that of the Detroit-type pressure switch. You will find the Detroit-type pressure switch discussed later in this chapter. The temperature switch is actually activated by pressure. The element senses a temperature change as a change of internal pressure of a sealed gas, air-filled bulb, or helix. Figure 3-5 shows you the two types of sensing elements.

Construction

You can connect the bulb and helix units to the switch section. The bulb unit (figure 3-5, item A) is normally used when you need to control liquid temperatures. However, it may control air or gas temperatures. This only happens if the circulation around it is rapid and the temperature changes at a slow rate.

The helical unit (figure 3-5, item B) has been specifically designed for air and gas temperature control circuits. For the thermal unit to be most effective, you must locate it at a point of unrestricted circulation. This is so it can "feel" the average temperature of the substance you wish to control.

Some switches are stamped WIDE DIFFERENTIAL. Differential is the difference between the opening and closing setpoint of the switch. These switches are adjusted in the same manner described for the regular controls. However, because of slight design changes, it is possible to get wider variation in differential settings.

Maintenance

When adjusting temperature controls, allow several minutes for the thermal unit to reach the temperatures of the surrounding air, gas, or liquid. Then set the operating adjustments. After adjusting the operating range of pressure or temperature controls, check the operation through at least one complete cycle. If you find variation from the desired operation value, go through the entire procedure again. Observe the operation through another complete cycle.

Operating Adjustments

To set the operating range of the switch, turn the differential adjustment screw (figure 3-6)

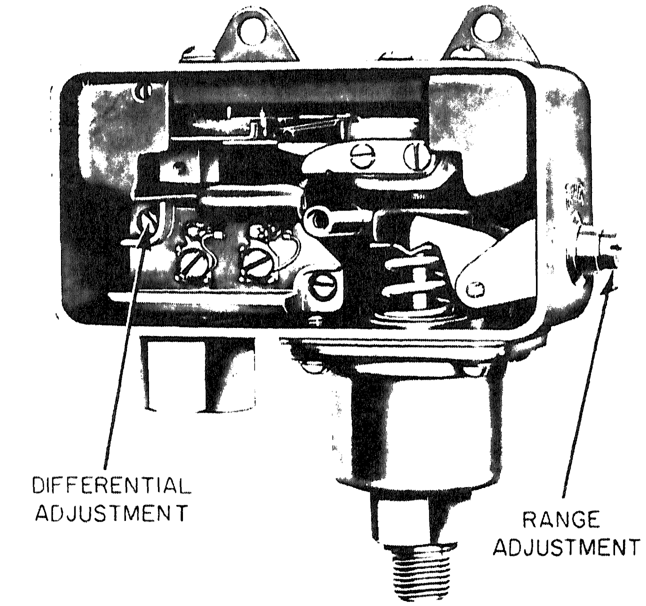

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Figure 3-6.—Detroit-type switch.

counterclockwise against the stop for minimum differential. Bring the pressure to the value at which you want the circuit to close. If the switch contacts are open at this pressure, turn the range screw slowly clockwise until the contacts close. If the contacts are closed when the desired pressure is reached, turn the range screw counterclockwise until the contacts open; then turn the screw slowly clockwise until the contacts close. These adjustments set the closing pressure.

The pressure (keep in mind that changes in temperature are converted to changes in pressure) is now raised to the point where you want the circuit to open. Since the differential adjustment is now set at minimum, the circuit will probably open at a lower pressure than desired; therefore, turn the differential adjustment screw clockwise to widen the differential. Turn until the desired opening pressure is obtained.

LIQUID AND PRESSURE SENSORS

In a gas turbine propulsion plant, you will have to monitor systems and tanks for pressure or liquid level. Sometimes you are only required to know if a level or pressure exceeds or goes below a certain preset parameter. Other circumstances require that you know the exact level or pressure. If only a predetermined limit is needed, you can use a float or pressure switch. This will make contact when the setpoint is reached and will sound an alarm. If you need to know a specific level or pressure, then you must use a variable sensing device. The sensor used for indicating a tank level is commonly called a tank level indicator (TLI). This sensor will tell you the exact amount of liquid in a tank. If you need to know a variable pressure, then you must use a pressure transducer. Pressure transducers will give you the exact pressure at the point the sensing line is installed.

GSEs maintain and troubleshoot all these devices. The following pages will describe the operation of each of these sensors and their applications. Refer to the manufacturers' technical manuals for more information on the procedures used to adjust each type of device.

TANK LEVEL INDICATORS

Many tank levels on gas turbine ships are monitored to provide the exact liquid level in them. Fuel tanks, for example, are monitored to ensure they do not overflow. They are also monitored to let the engineer officer know the amount of fuel aboard the ship. The sensors used to monitor these levels are TLIs. Each of the level-monitored tanks contains a level transmitter. A typical transmitter section contains a voltage divider resistor network extending the length of the section. Magnetic reed switches are tapped at 1-inch intervals along the resistor network. The reed switches are sequentially connected through series resistors to a common conductor. This network is enclosed in a stem that is mounted vertically in the tank. A float containing bar magnets rides up and down the stem as the level changes.

In operation, a calibrated voltage is supplied to the ends of the divider network from an external source. As the float moves up or down the stem, the reed switches are closed in a two-at-a-time, three-at-a-time, two-at-a-time sequence. Figure 3-7 shows you the arrangement of the switches in the stem. When two switches are closed, the effective tap point is halfway between the two switches. When three switches are closed, the effective tap point is at the middle of the three. As a result, the effective tap point changes in half-inch increments. The common conductor voltage is therefore proportional to the float level within a half-inch of travel. This voltage provides tank level information to the system.

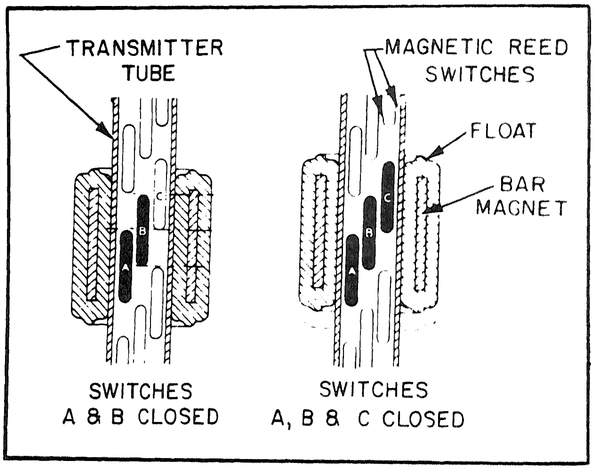

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Figure 3-7.—Arrangement of magnetic switches in the stem of a tank level indicator.

In many tanks, you have to use more than one transmitter section to measure the full range. The physical arrangement of some tanks makes this necessary. When multiple sections are used, they are electrically connected as one continuous divider network.

Two types of floats are used. In noncompensated tanks, the float is designed to float at the surface of the fuel oil (FO) or JP-5. For seawater compensated tanks, the float is designed to stay at the seawater/fuel oil interface.

CONTACT LEVEL SENSORS

Many times you do not have to know the exact level of a tank until it reaches a preset level. When this type of indication is needed, you can use a contact or float switch. Two types of float level switches are used on gas turbine ships. One type is the lever operated switch. It is activated by a horizontal lever attached to a float. The float is located inside the tank. When the liquid level reaches a preset point, the lever activates the switch.

The other type of level switch uses a magnet-equipped float sliding on a vertical stem. The stem contains a hermetically sealed, reed-type switch. The float moves up and down the stem with the liquid level. It magnetically opens or closes the reed switch as the float passes over it. Figure 3-8 shows the construction of the magnetically operated float switch. Magnetic-type float switches may be constructed with more than one

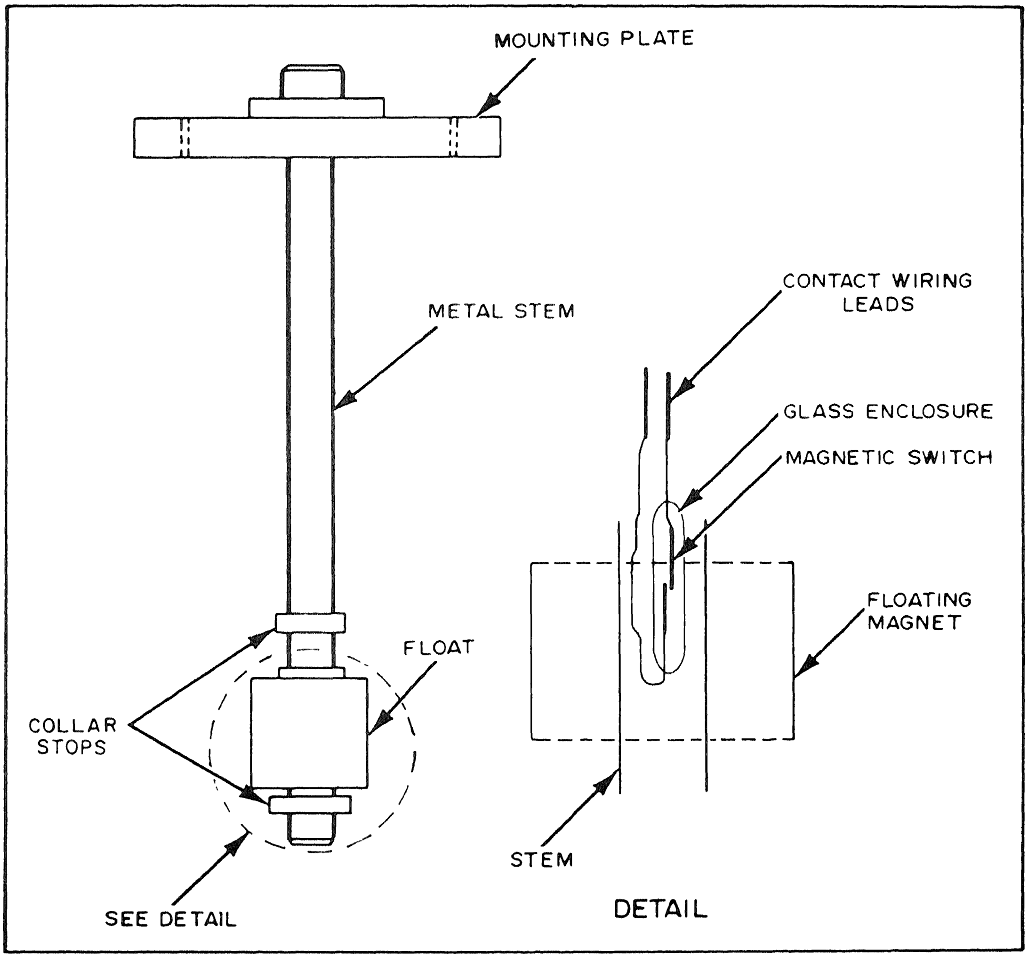

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Figure 3-8.—Magnetic-type float switch.

float on a stem. This type of switch can detect multiple levels in the same tank, such as a high- and low-level alarm. You may also wire multiple stems together to provide this same feature.

To ensure their proper operation, you have to periodically clean float switches. Dirt may accumulate between the float and the stem. This will prevent the float from traveling freely. Normally, you can clean the stem and float with soap and water. This should remove the dirt and make the float move freely.

If the switch does not work after cleaning, it may have slipped out of adjustment. The switch itself is not adjustable. However, you can move the float to set the switch activating point. The magnetic switch will only activate with the float in one position. To find that position, you have to use an ohmmeter or other continuity tester. Hook the meter to the switch leads. Loosen the stop collar and slide the float until the switch activates. Adjust the collar to within one-fourth inch of the float and tighten the collar setscrews. After adjusting, ensure that you have enough travel to allow the switch to turn on and off.

If you find you cannot set the magnetic-type float switch, the problem will probably be inside the stem. If this is the case, you may have to replace the entire probe assembly.

PRESSURE SWITCHES

Often when a measured pressure reaches a certain maximum or minimum value, a pressure sensing device is activated. This may be in the form of an alarm to sound a warning or a light to give a signal. It could also be used for an auxiliary control system to be energized or deenergized. This requires closing electrical contacts. The Detroit-type pressure switch shown in figure 3-9 is a device commonly used for this purpose. This switch is normally contained in a metal case with a removable cover. It is equipped with a pressure port and an electrical connector. The pressure switch converts, through a set of contacts, the motion of a diaphragm, or bellows into an electrical signal. Pressure switches are used to sense gage or differential pressures on pneumatic as well as hydraulic systems. They are

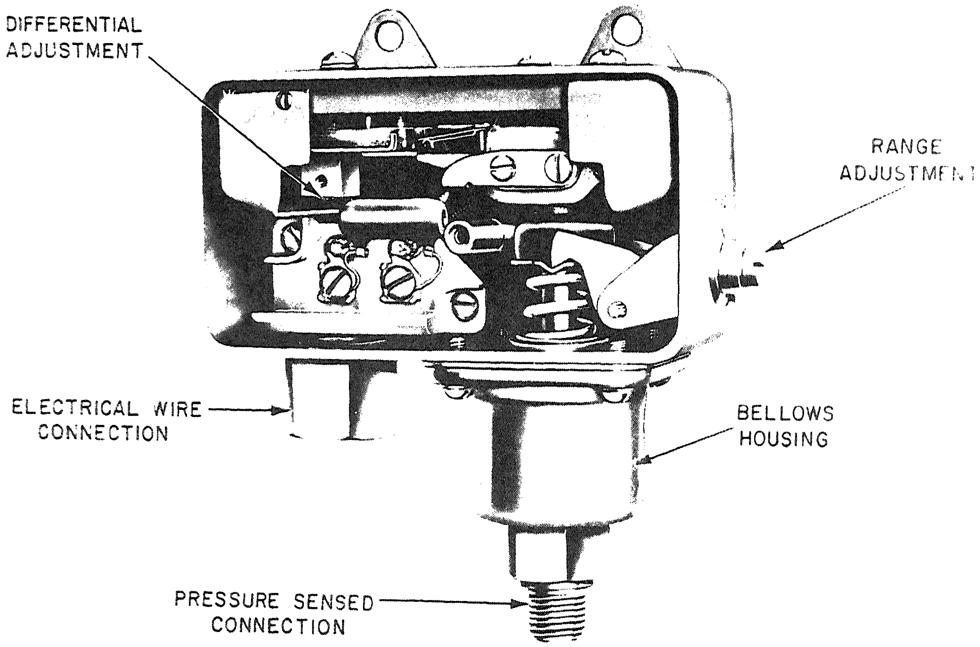

Figure 3-9.—Detroit-type pressure switch. 77.119

manufactured in many sizes and configurations, but all perform basically the same function.

Construction of Pressure Switches

One of the simplest types of pressure switch is the single-pole, single-throw, quick-acting type shown in figure 3-9. This switch contains a seamless metallic bellows in the housing, which is displaced by changes in pressure. The bellows works against an adjustable spring which determines the amount of pressure needed to actuate the switch. Through suitable linkages, the spring causes the contacts to open or close the electrical circuit. This is done automatically when the operating pressure falls or rises from a specified value. A permanent magnet in the switch mechanism provides a positive snap on both the opening and the closing of the contacts. This snap action prevents excessive arcing of the contacts. The switch is constantly energized. However, it is the closing of the contacts that energizes the entire electrical circuit.

As mentioned above, you can find switches in many sizes and configurations. The switch that is used will depend upon its application. Besides single-pole, single-throw switches, some switches have more than one pole and more than one throw.

The number of POLES of a switch indicates the number of terminals at which current can enter the switch. The number of THROWS indicates the number of different circuits that can be controlled by each pole. By counting the number of points where current enters the switch, you can determine the number of poles. To determine this, you can use the schematic symbol or the switch itself. By counting the number of different points each pole can connect with, you can determine the number of throws.

For additional information, refer to Module 3 of the Navy Electricity and Electronics Training Series (NEETS), *Introduction to Circuit Protection, Control, and Measurement*, NAVEDTRA 172-03-00-79.

Setting Pressure Switches

To set a pressure switch, you first have to set a known pressure in the operational range of the switch. Normally, you do this by using a test setup like that shown in figure 3-10. In an emergency,

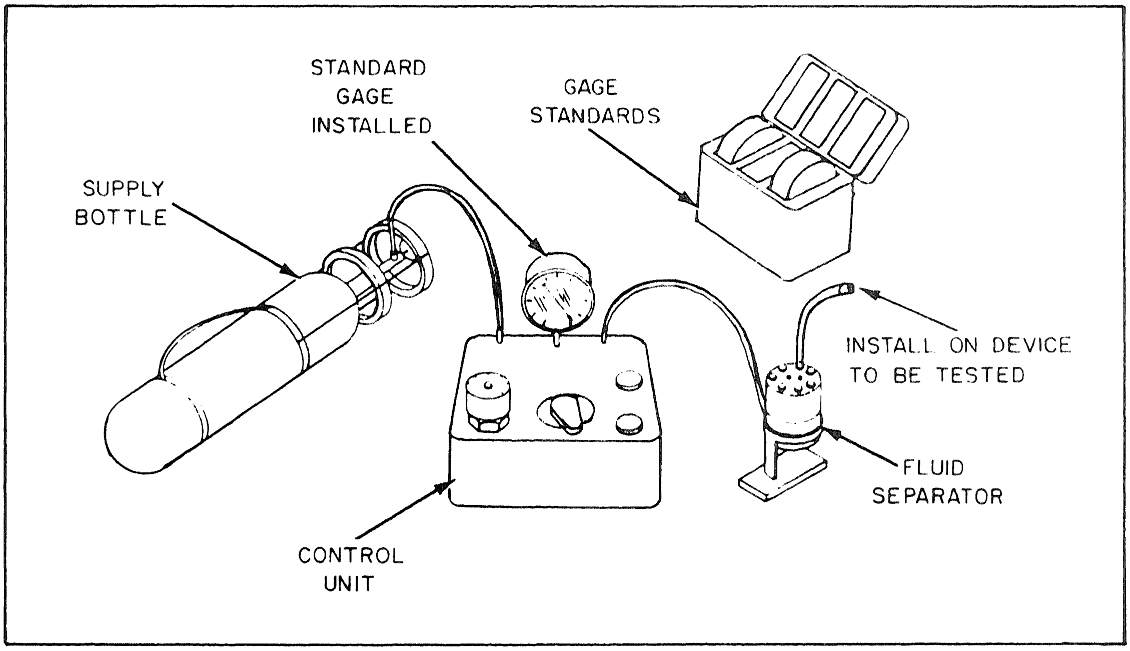

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Figure 3-10.—Typical setup for calibrating a pressure device.

you can use the pressure of the system in which the switch is installed. But you should reset the switch as soon as possible using a calibrator. Many types of pressure calibrators are used in the fleet. Refer to the manufacturer's technical manual for the correct operating instructions for your unit. Another useful source of information on calibration equipment is *Instrumentman 3 & 2*, NAVEDTRA 10193-D.

After you have the calibration equipment set up, you must install a meter to check the contact close point. If the switch is still in place, you can use a voltmeter or multimeter. If you are bench testing the switch, use an ohmmeter. To set the pressure switch, bring the pressure to the point where you want the switch to close the circuit. If the meter shows the contacts are open, turn the range screw slowly counterclockwise until the contacts just close. If the contacts are already closed, turn the adjusting screw clockwise until the contacts open; then turn slowly counterclockwise until the contacts just close. This fixes the closing point.

Opening point is fixed by the differential. The opening point will always be higher than the closing point. You can adjust the differential slightly by adjusting the differential screw.

PRESSURE TRANSDUCERS

A transducer is a device that receives energy from one system and retransmits it to another system. The energy retransmitted is often in a different form than that received. The type of transducer discussed in this section is the pressure transducer. This device receives energy in the form of pressure and retransmits energy in the form of electrical current. Pressure transducers, like pressure switches, are widely used in ship propulsion and auxiliary machinery spaces. They are used to monitor alarms and machinery operation.

Pressure transducers are generally designed to sense absolute, gage, or differential pressure. The typical unit (figure 3-11) receives pressure through the pressure port. It transmits an electrical signal of 4 to 20 mA d.c., proportional to the pressure input, through the electrical connector. Pressure transducers are available in pressure ranges from 0 to 6 inches water differential to 0 to 10,000 psig. Regardless of the pressure range of a specific unit, the electrical output is always the same. It is always 4 to 20 mA d.c. proportional to the input. The electrical signal is displayed on an analog meter or a digital readout located on one of the control consoles.

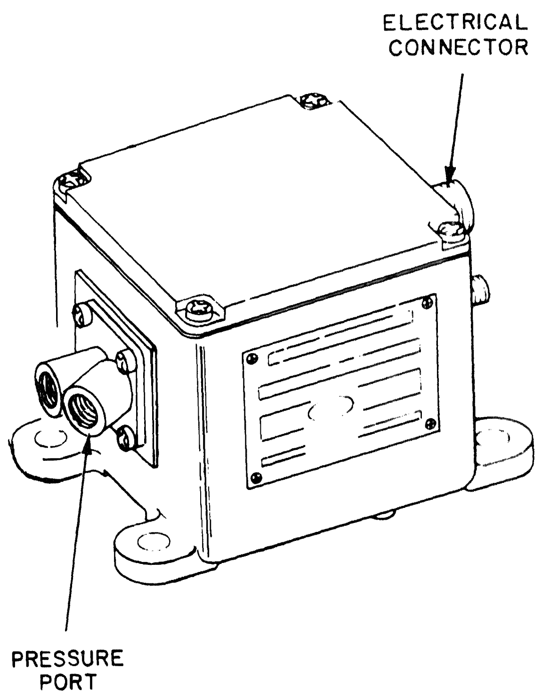

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Figure 3-11.—Pressure transducer assembly.

Overall Functional Description

The transducer senses vacuum or pressure inputs. The input is converted to a proportional differential d.c. signal current by the sensor assembly. Then it is transmitted to the signal conditioner assembly. The signal conditioner assembly supplies 2 mA regulated current to the sensor assembly. It converts the differential d.c. signal current from the sensor to a 4 to 20 mA d.c. signal. The d.c. signal is then directed to display devices through the electrical connector. Figure 3-12 is a simplified block diagram of the transducer assembly.

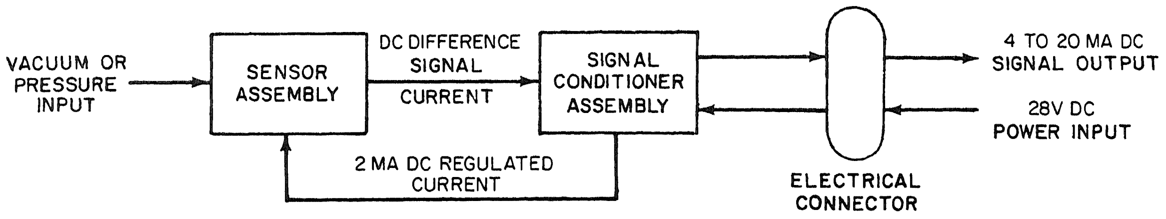

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Figure 3-12.—Transducer block diagram.

FUNCTIONAL DESCRIPTION OF THE SENSOR ASSEMBLY.—The sensor assembly consists of three basic interconnected components. A pressure sensing assembly is enclosed within a welded port fitting assembly. The sensor assembly consists of a pressure port fitting and diaphragm assembly seal welded together. The diaphragm assembly contains four strain gages in a bridge arrangement and a seal welded end cap. The end cap provides a sealed (50 microns Hg) or atmospheric pressure reference chamber for the diaphragm. The wires of the strain gage pass through a hermetic header in the end cap and connect to the signal conditioner. The header is soldered to the end cap. A regulated current of about 2 mA d.c. is supplied to the bridge circuit from the signal conditioner. When a pressure or vacuum input is not applied to the diaphragm, the resistance of the strain gage bridge circuit is balanced. The two signal current outputs from the bridge circuit to the signal conditioner will be equal. A pressure or vacuum input to the diaphragm causes the resistance of the strain gages in the bridge circuit to change. This causes the bridge circuit to be unbalanced. The two signal currents to the signal conditioner assembly will now be different. The difference in signal currents will be proportional to the pressure or vacuum applied to the diaphragm.

FUNCTIONAL DESCRIPTION OF THE SIGNAL CONDITIONER.—The signal conditioner assembly consists of a printed circuit board with solid-state electronic components and circuits to operate the transducer. A test jack may be mounted on the circuit board for ease in calibrating and testing the transducer. The signal conditioner consists of five circuits. The circuits are a sensor constant current circuit, a difference signal current boost circuit, and a current buffer amplifier circuit. Other circuits are a sensor zero adjust circuit and a signal current span adjust circuit. The major electronic component is a differential signal current amplifier.

FUNCTIONAL OPERATION OF THE SIGNAL CONDITIONER.—Twenty-eight volts d.c. supply voltage powers three circuits. They are the sensor constant current circuit, the difference signal current boost circuit, and the current buffer amplifier circuit. The sensor constant current circuit provides a stable reference current to the sensor strain gage bridge circuit. The sensor assembly uses the reference current to convert a vacuum or pressure input to a proportional difference signal. The signal is equal to the difference of the two current outputs of the strain gage bridge circuit. The difference signal from the sensor is amplified by a differential amplifier. The amplified output differences signal drives the current buffer amplifiers to supply a proportional 4 to 20 mA d.c. signal through the span adjust circuit. The 4 to 20 mA d.c. signal is then transmitted. It is transmitted through the test jack and the electrical connector to the signal display devices. The sensor zero adjust circuit is used to adjust the 4 mA d.c. output of the differential amplifier.

Pressure Transducer Calibration

Pressure transducers are usually calibrated on a bench prior to installation. The equipment you

will need is shown in figure 3-13. After setting up your test equipment as shown, you will be ready to start calibrating the transducer. Turn the power supply on and allow it to warm up. Ensure its output is 28 volts d.c. Set the decade box resistance to 500 ohms. Cycle the input pressure or vacuum slowly from 0 to 100 percent several times to ensure smooth operation.

CAUTION

Exceeding the 100 percent pressure will damage the strain gage and make it inoperable.

Adjust the pressure or vacuum supply to zero percent of the range. Next, turn the zero adjust resistor for a digital voltmeter reading between 1.92 and 2.08 volts d.c. Adjust the input supply to 100 percent of the range. Set the span potentiometer for a voltmeter reading between 9.92 and 10.08 volts d.c. Continue setting the zero and span adjustments until your voltage readings are both within the specified ranges. When the required ranges are achieved, the transducer is set and you may then install it in the required location. For further information on calibrating or repairing transducers, refer to the technical manual Pressure Transducer - Strain Gage Assembly, NAVSEA 0987-LP-059-5010. Additional information on calibration of the LM2500 transducers is found in the LM2500 technical manual series.

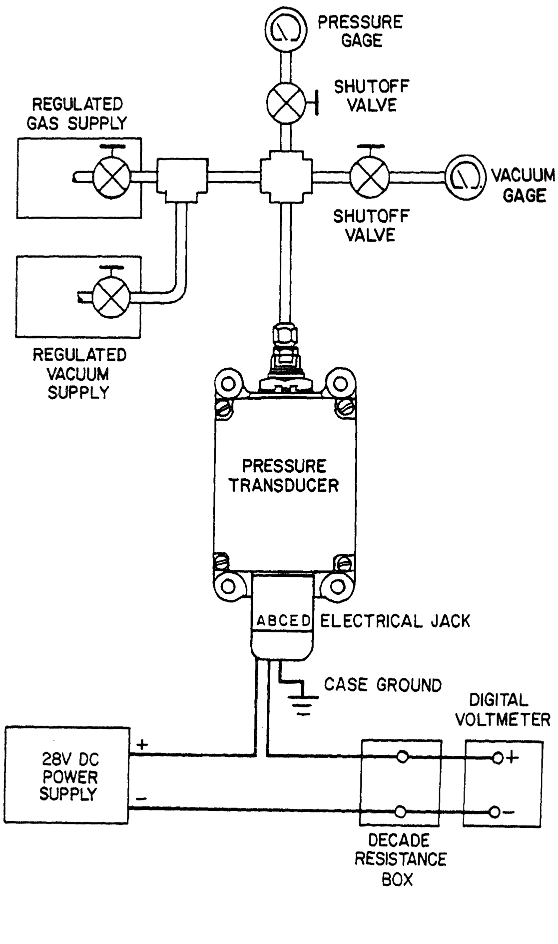

Figure 3-13.—Calibration setup for a pressure transducer.

MISCELLANEOUS SENSORS AND SIGNAL CONDITIONERS

Several of the sensors used in the gas turbine propulsion plant are not pressure, temperature, or liquid-type sensors. These devices, such as icing, speed, vibration, or ultraviolet, are used to monitor or protect the gas turbine engine (GTE) from damage. We will discuss these unique sensors in this section.

ICE DETECTOR SYSTEMS

Under certain atmospheric conditions, ice can form in the inlet airflow system. This can happen when the temperature falls below 41 °F and the relative humidity is above 70 percent. The formation of ice in the inlet has two detrimental effects. It can restrict airflow to the gas turbine with a resultant loss of power. Also, if allowed to build up in large quantities, ice chunks can break off. They can go through the gas turbine compressor causing foreign object damage (FOD).

The sensor is located in the lower left corner of the inlet barrier wall. It senses inlet temperature and humidity and transmits proportional electrical signals to the signal conditioner. The signal conditioner is mounted on the underside of the base. It provides a signal for the icing alarm at the propulsion console when icing conditions exist. The anti-icing process is operator enabled and controlled by a signal from a sensor in the intake stack.

Ice Detectors

The detector, shown in figure 3-14, consists of a sensor assembly mounted in a body secured to a mounting plate assembly. The body and mounting plate are machined from stainless steel. A filter cover assembly protects the sensing element while allowing the passage of atmospheric air over two sensors. The sensor assembly is retained in the body by a circlip and collar. It consists of a temperature sensor and a humidity sensor. Electrical connection to the sensing element is made through a fixed plug secured to the mounting plate.

Changes in temperature of the air flowing over the sensor assembly vary the electrical resistance of the thermistor temperature sensor. As temperature decreases, the resistance of the thermistor increases; at 41 °F, resistance is about 2.4 K ohms. The change in resistance modifies a d.c. signal in the ice detector signal conditioner.

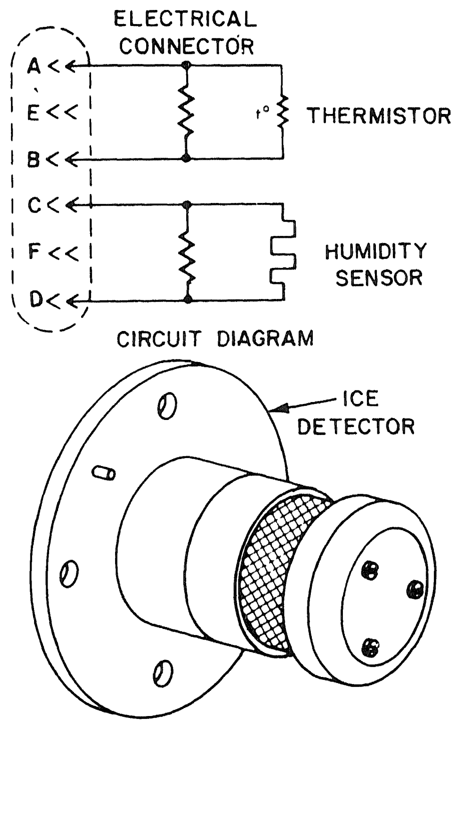

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Figure 3-14.—Ice detector.

Changes in the moisture content of the air flowing over the sensor assembly vary the electrical resistance of the humidity sensor. The humidity sensor is a salt-treated wafer. As it absorbs moisture from the surrounding air, its resistance decreases as the humidity increases; at 70 percent relative humidity, resistance is about 435 K ohms. The change in resistance affects the feedback to an amplifier in the ice detector signal conditioner.

Ice Detector Signal Conditioners

The signal conditioner (figure 3-15) consists of two printed circuit-board assemblies, a transformer, and a relay and capacitor. The printed circuit-board assemblies and transformer are mounted on spacers secured to the bottom and one side of the box. The capacitor and relay are secured to the side of the box opposite the transformer. The box is closed by a cover bearing identification labels. Two screws cover access holes to two potentiometers positioned on the upper circuit-board assembly.

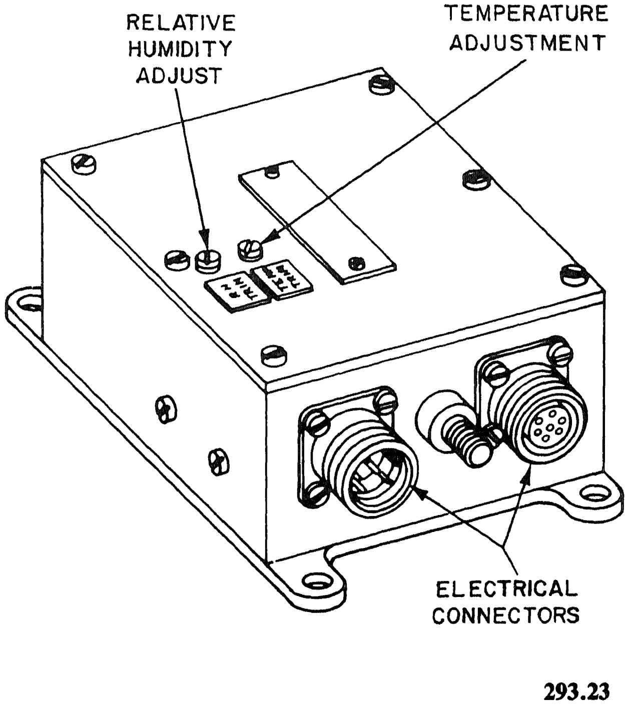

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Figure 3-15.—Ice detector signal conditioner.

Figure 3-16 is a block diagram of the ice detector and the signal conditioner. By referring to the above figure and reading the following two paragraphs, you will understand how the system senses the icing conditions.

The amplifier is fed with a stabilized d.c. supply and an input from a square-wave generator. The relative humidity sensor is connected in the feedback loop of the amplifier. The temperature dependent resistor (temperature sensor) provides a correction signal to the amplifier. It also provides an input signal to the temperature trigger circuit. The temperature sensor is operated at a very low d.c. voltage. The low voltage is used to reduce error in temperature measurement due to self-heating.

The output from the amplifier is fed to the relative humidity trigger circuit. Both the temperature and relative humidity trigger circuits are set to operate at predetermined levels. These predetermined levels are 41 °F and 70 percent relative humidity. When the temperature and humidity are sensed, outputs from the two trigger circuits are fed to a gate; the gate operates in the "and" mode. Thus, when the relative humidity is greater than the preset value at an ambient temperature of less than the preset value, the gate will produce an output. The output from the gate circuit energizes a relay causing a contact opening. The contact opening operates a warning device on the propulsion console.

SPEED SENSORS

One of the more important parameters sensed in a gas turbine propulsion plant is speed. Speed is measured on reduction gears and gas turbines. The reduction gear speed is monitored to inform the propulsion plant operators of the propeller shaft speed. Gas turbine speed is measured to ensure the turbine does not overspeed. Also, gas turbine speed is used as an input to the control systems of the engine. Two types of speed sensors are used to measure the required speeds. One type is the tachometer generator, used on reduction gears. The other type is the magnetic speed pickup, used to sense gas turbine speeds. In some applications, it is used to sense reduction gear speeds.

Magnetic Speed Pickup

The magnetic speed pickup is the most common type of speed sensor found in gas turbine propulsion plants. It is used for sensing gas turbine speed on the LM2500 and Allison 501-K17. It is also used to measure reduction gear speed for controllable pitch propeller (CPP) systems on the FFG-7 class. The DD-963 class

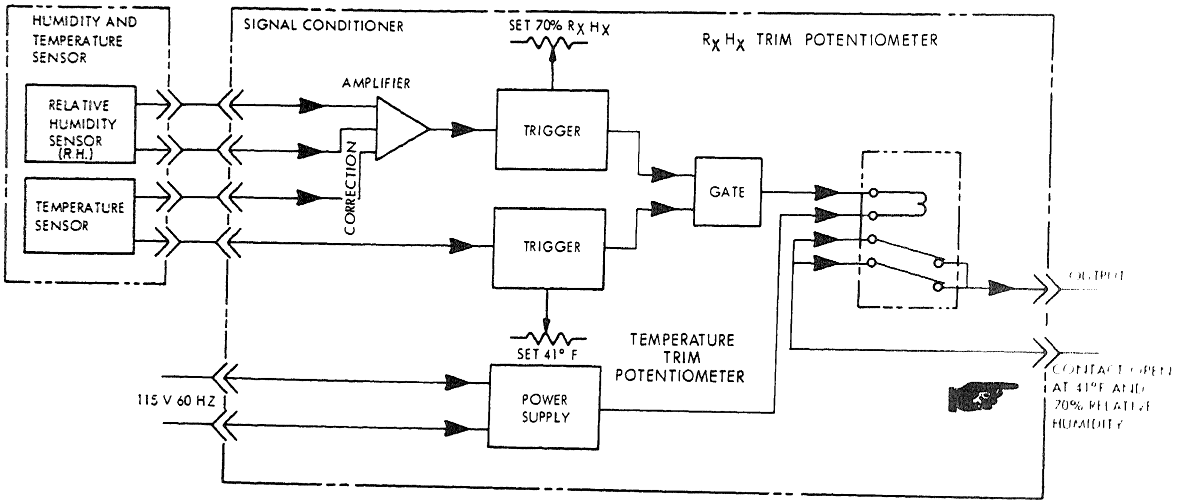

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Figure 3-16.—Ice detection system block diagram.

MRG uses magnetic speed pickups for sensing clutch engagement speeds.

Magnetic speed pickups sense speed by using a toothed gear which cuts the magnetic field of the pickup. The output of the sensor is a square wave a.c. voltage. This voltage is converted to a proportional d.c. voltage in a signal conditioner. The output of the signal conditioner is used in control functions as well as for indications of equipment speed. Figure 3-17 shows the magnetic speed pickup used in an LM2500 power turbine.

The most important thing to remember when you replace a speed pickup is to check the depth setting. The depth clearance is measured with either a special tool supplied by the equipment manufacturer or a depth micrometer. You can set the proper clearance by using either shims or locknuts. If you do not set the clearance properly, the magnetic sensor will either be too close to the toothed gear or too far from it. If it is too close, it may be damaged by the rotating gear. If it is too far from the gear, the unit will fail to give the proper voltage signal. Always refer to the proper manufacturers' technical manuals when replacing a magnetic speed sensor.

Tachometer Generators

Main reduction gears (MRGs) use tachometer generators to provide electrical signal for remote indication of propulsion shaft speed. The output of the tachometer generator is voltage pulses proportional to the speed of the propeller shaft. The tachometer signal is amplified. Then it is sent to the propulsion electronics for use in data and bell logging and display of shaft speed. You will find more information on tachometer generators by referring to the related technical manual found on your ship.

VIBRATION SENSORS

One of the first indications of internal damage to gas turbines is high vibration. High vibration conditions can be indications of failed bearings, damaged blading, or a dirty compressor. The GTEs found on Navy ships use velocity-type

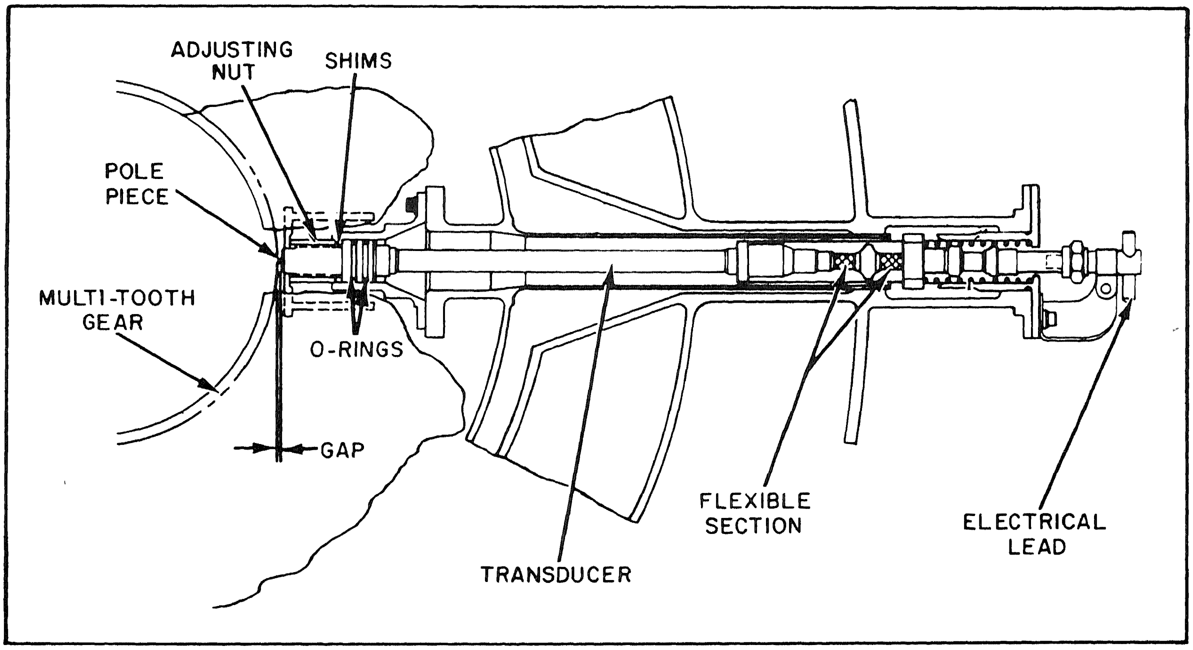

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Figure 3-17.—Magnetic speed pickup used on the LM2500 power turbine.

vibration pickups. Figure 3-18 shows a typical velocity-type vibration pickup used on gas turbines.

The vibration pickup is a linear velocity transducer (transfers mechanical energy to electrical energy). The magnetic circuit is closed through the circular air gap between the pole piece sleeve in the case and the pole pieces on the magnet assembly. The air gap is interrupted by the coils. (The flux field in the air gap is normally aligned with the approximate midpoint of the two coils by the centering action of the two magnet springs.) As the engine vibrates, the rigidly mounted case and coil move with the vibration. Due to its inertia, the magnet assembly remains stationary. The coil windings cut through the magnetic field in the air gap inducing a voltage in the coils. This voltage is proportional to the velocity of vibration. You may use vibration filters to filter out the frequencies that are transmitted from sources external to the gas turbine. Using these filters, you can narrow the cause of vibration down to one section of an engine. On the LM2500 the PT operates at a slower speed than the gas generator (GG). By use of filters, you are able to determine where the engine vibration is located. You can tell if it is from the lower frequency PT or the higher frequency GG.

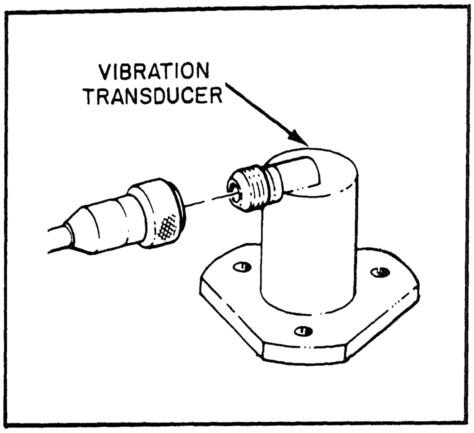

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Figure 3-18.—Velocity-type vibration transducer.

ULTRAVIOLET FLAME DETECTOR

Ultraviolet (UV) flame detectors are used in GTMs to detect the presence of fire. These sensors are used along with temperature sensors in the LM2500. They are used alone in the Allison 501-K17 for fire protection. The fire detection system alerts the operator of fire in the module. It also activates the fire stop sequence and releases fire-extinguishing agents to extinguish the fire on the Allison 501-K17 and on the LM2500 of the twin shaft ships.

Flame Detector

The flame detector (figure 3-19) is an electronic tube that responds to UV radiation in ordinary flames. It is insensitive to infrared (IR) and ordinary visible light sources. The tube has two symmetrical electrodes within the gas-filled envelope. It operates on pulsating d.c. current. Alternating current enters the detector and is stepped up by a transformer. This a.c. is then rectified to pulsating d.c. which is fed to the UV sensor. Ultraviolet light containing wavelengths in the range of 1900 to 2100 Angstrom units ionize the gas in the tube. This allows the current to flow through the tube. The current then goes to a pulse transformer which couples it to the signal conditioner.

Flame Detector Signal Conditioner

The flame detector signal conditioner (figure 3-20) is contained in a metal box. The box is attached to the underside of the base/enclosure on the LM2500. On the Allison 501-K17, the unit is located in the alarm terminal box on the generator end of the module base.

Identical detector cards (one for each UV sensor) are located in the signal conditioner. The detector card amplifies, rectifies, and filters the current pulses from the UV sensor. This provides an output voltage level proportional to the UV light level at the UV sensor.

The detector outputs are "Diode OR-ed" and applied to the comparator card input. The comparator card is located in the signal conditioner.

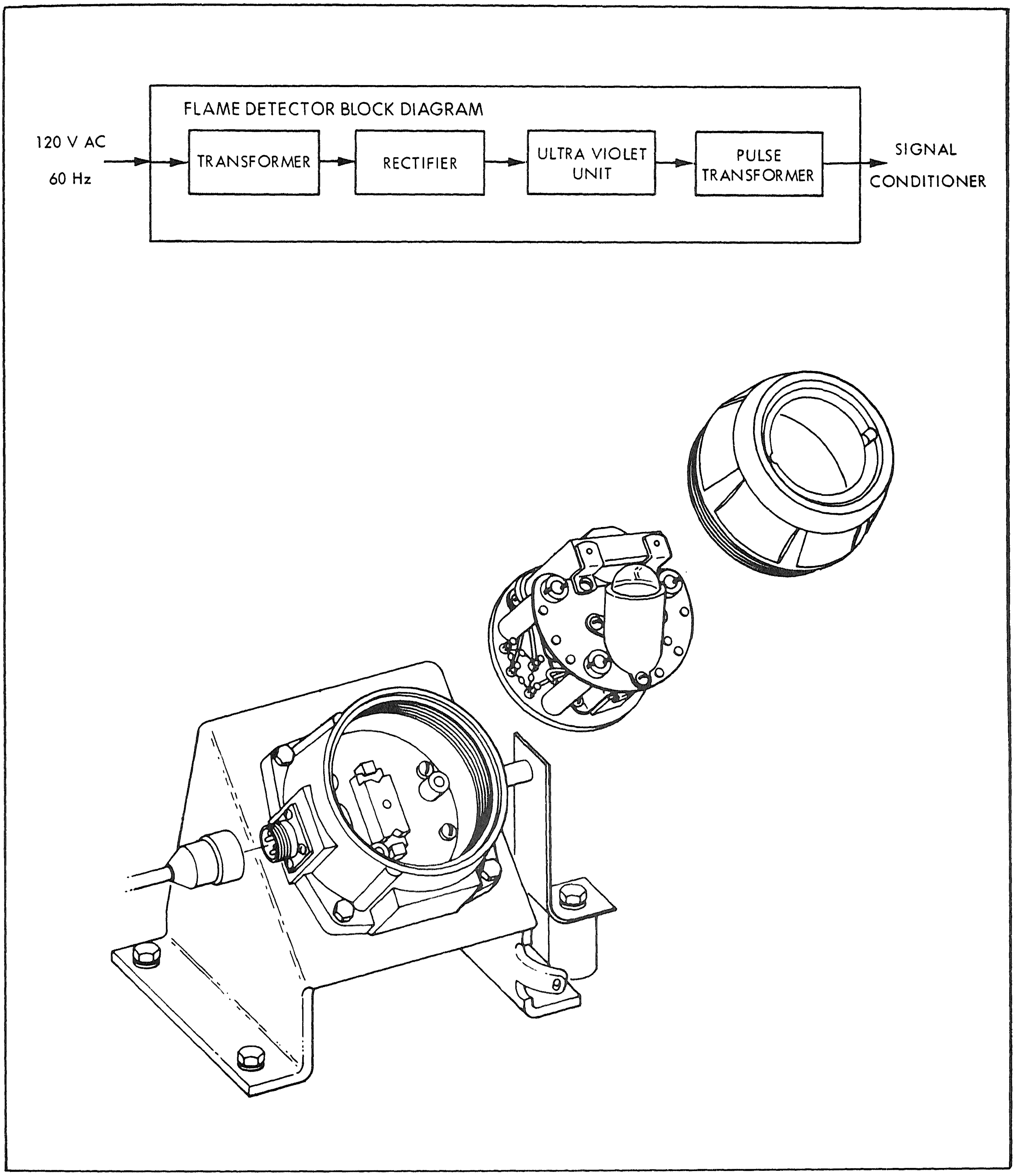

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Figure 3-19.—Flame detector block diagram and typical flame detector.

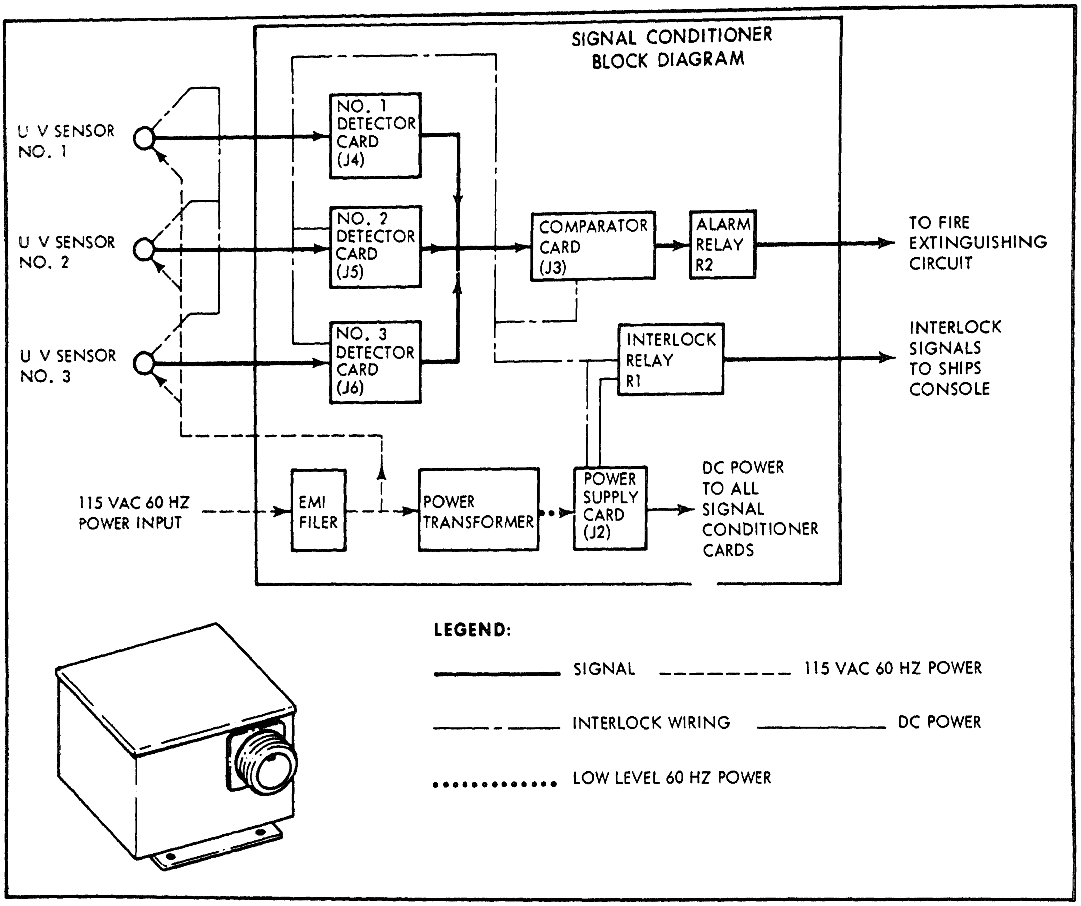

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Figure 3-20.—Flame detector signal conditioner block diagram and typical signal conditioner unit.

It is a power amplifier and provides sufficient power to energize the alarm control relay R2. This occurs when the input signal exceeds a threshold level set by potentiometer R9.

The energized alarm control relay contacts complete the alarm control circuitry external to the GTMs. This results in an alarm indication. The interlock relay R1 energizes when the following conditions are met: (1) all UV sensors are properly connected, (2) all circuit cards are properly installed in the signal conditioner, and (3) all harness connectors are properly installed.

The power supply card is located in the signal conditioner at connector J2. It converts the a.c. outputs of a power transformer to d.c. voltage levels required for the signal conditioner.

ELECTRICAL INDICATING INSTRUMENTS

Electrical indicating instruments (meters) are used to display information that is measured by some type of electrical sensor. Meters on the control console, although they display units such as pressure or temperature, are in fact d.c. voltmeters. The signal being sensed is conditioned by a signal conditioner. It is then converted to 0 to 10 volts d.c., proportional to the parameters being sensed. Electrical values, such as wattage and current, are measured and displayed at ship's service switchboards. The electrical values are then conditioned and displayed on the electric plant

console. The meters on the electrical plant console are also 0 to 10 volts d.c. type of meters. The meters we will discuss in this chapter are found on the ship's service switchboards. Normally, shipboard repair is not done on switchboard meters. If you suspect the switchboard meters are out of calibration or broken, you should have them sent to a repair facility. You can find more information on the theory of operation of these meters in the Navy Electricity and Electronics Training Series, (NEETS), Module 3, *Introduction to Circuit Protection, Control, and Measurement*, NAVEDTRA 172-03-00-79.

VOLTMETERS

Both d.c. and a.c. voltmeters determine voltage the same way. They both measure the current that the voltage is able to force through a high resistance. This resistance is connected in series with the indicating mechanism or element. The voltmeters installed in switchboards and control consoles (figure 3-21) all have a fixed resistance value. Portable voltmeters, used as test equipment, usually have a variable resistance. These resistances are calibrated to the different ranges that the meters will display. The normal range for the switchboard and electric plant meters is 0 to 600 volts.

AMMETERS

Ammeters (figure 3-22) are used to indicate the current passing through a conductor. Different types of ammeters are used for either alternating current (a.c.) or d.c. However, any a.c. ammeter will indicate on d.c. with a lower degree of accuracy.

The construction of installed ammeters is such that they are not able to handle the current that passes through the conductor being measured. Ammeters are required to be connected in series with the circuit to be measured. Since the meters cannot handle the high switchboard current, the switchboard ammeters operate through current transformers. This arrangement isolates the instruments from line potential. The current transformer produces in its secondary a definite fraction of the primary current. This arrangement makes it possible to measure large amounts of current with a small ammmeter.

CAUTION

The secondary of a current transformer contains a dangerous voltage. Never work around or on current transformers without taking proper safety precautions.

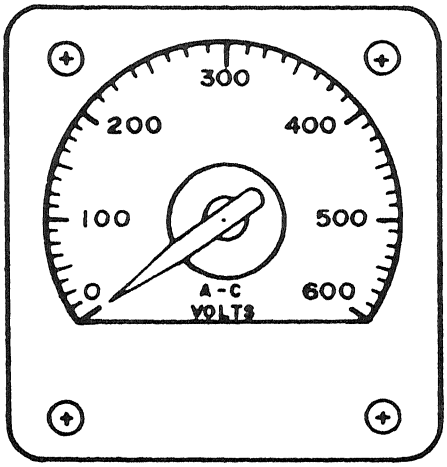

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Figure 3-21.—A.c. voltmeter.

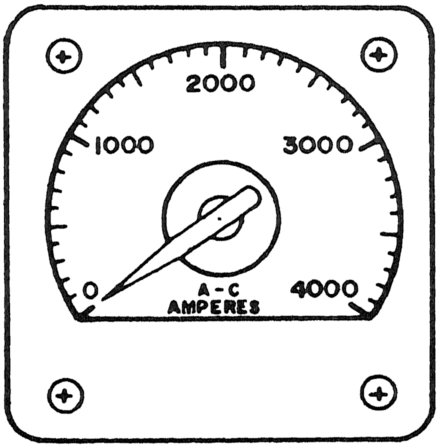

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Figure 3-22.—A.c. ammeter.

FREQUENCY METERS

Frequency meters (figure 3-23) measure the cycles per second rate of alternating current. The range of frequency meters found on gas turbine ships is between 55 Hz to 65 Hz. Frequency of the a.c. used on ships rarely varies below 57 Hz and seldom exceeds 62 Hz. A frequency meter may have a transducer that converts the input frequency to an equivalent d.c. output. The transducer is a static device employing two separately tuned series resonant circuits which feed a full wave bridge rectifier. A change in frequency causes a change in the balance of the bridge. This causes a change in the d.c. output voltage.

KILOWATT METERS

Wattage is measured by computing values of current, voltage, and power factor. The kilowatt meters used on ships automatically take these values into account when measuring kilowatt (kW) produced by a generator. Kilowatt meters are connected to both current and potential transformers to allow them to measure line current and voltage. The kW meter shown in figure 3-24 is similar to the ones used on gas turbine ships. Since each type of generator on gas turbine ships is rated differently, the scale will be different on each class ship.

The amount of power produced by a generator is measured in kilowatts. Therefore, it is important when balancing the electrical load on two or more generators to ensure kW is matched. Loss of kW load is the first indication of a failing generator. For example, two generators are in parallel and one of the two units experiences a failure. To determine which of the two units is failing, you compare the kW reading. Normally, the generator with the lowest kW would be the failing unit. However, you should know that there is one case where this is not true. During an overspeed condition, both units will increase in frequency. But the failing unit will be the one with the higher kW load.

SYNCHROSCOPES

Before connecting a three-phase generator to bus bars already connected to one or more other generators, certain conditions must prevail. A synchroscope is the device you will use to find out if the following conditions have been met.

1. Phase sequence must be the same for generator and bus bars.
2. Generator and bus-bar voltage must be the same.
3. Generator and bus-bar frequency must be the same.

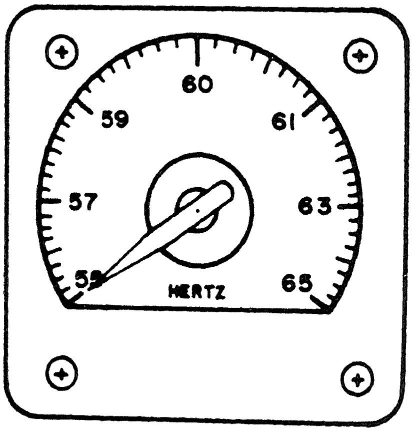

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Figure 3-23.—Frequency meter.

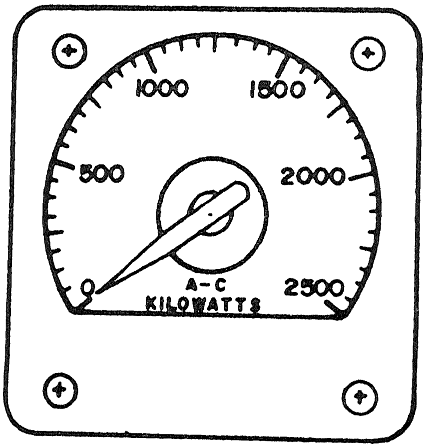

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Figure 3-24.—Kilowatt meter.

4. Generator frequency must be practically constant for an appreciable period of time.

5. The generator and bus-bar voltage must be in phase. They must reach their maximum voltages at the same time. This is so that when connected, they will oppose excessive circulation of current between the two machines.

A synchroscope is shown in figure 3-25. It is basically a power factor meter connected to measure the phase relation between the generator and bus-bar voltages. The moving element is free to rotate continuously. When the two frequencies are exactly the same, the moving element holds a fixed position. This shows the constant phase relation between the generator and bus-bar voltage. When the frequency is slightly different, the phase relation is always changing. In this case, the moving element of the synchroscope rotates constantly. The speed of rotation is equal to the difference in frequency; the direction shows whether the generator is fast or slow. The generator is placed on line when the pointer slowly approaches a mark. This mark shows that the generator and bus-bar voltages are in phase.

PHASE-SEQUENCE INDICATORS

The sequence in which the currents of a three-phase system reach their maximum values is determined by phase-sequence indicators. An example of this type of indicator is shown in figure 3-26.

Gas turbine ships have phase-sequence indicators installed in switchboards which may be connected to shore power. These instruments indicate whether shore power is of correct or incorrect phase sequence, prior to connecting shipboard equipment to shore power. Three-phase motors, when connected to incorrect phase-sequence power, rotate in the opposite direction.

The phase-sequence indicator has three neon lamps that light when all three phases are energized. A meter connected to a network of resistors and condensers shows correct or incorrect sequence on a marked scale.

SUMMARY

This chapter introduced you to many of the sensing and indicating devices found on gas turbine ships. Only the most common and frequently used devices were covered. You may come across other types of specialized sensors or indicating instruments not covered here. In this case, refer to the manufacturers' technical manuals. You have been referred to other sources of information to help you better understand the certain operational principles that were discussed in this chapter.

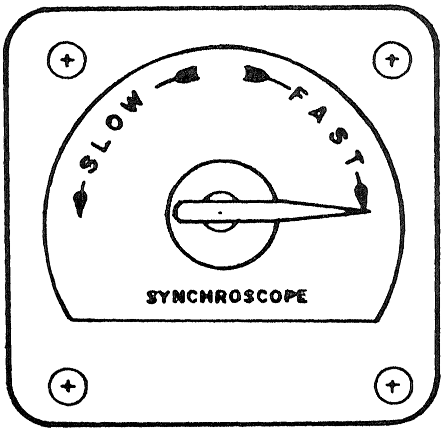

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Figure 3-25.—Synchroscope.

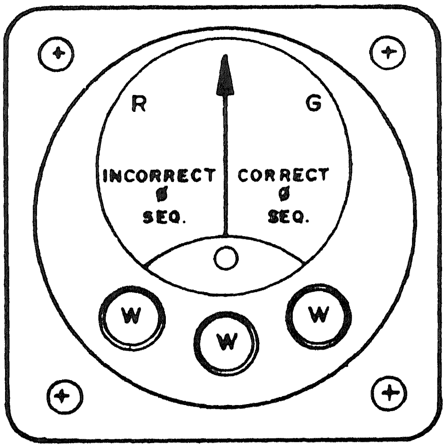

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Figure 3-26.—Phase sequence indicator.

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CHAPTER 4

FUNDAMENTALS OF GAS TURBINE ENGINES

This chapter will help you understand the history and development of gas turbines. You will become familiar with the basic concepts used by gas turbine designers. You will follow discussions of how the Brayton cycle describes the thermodynamic processes in a gas turbine. Also you will learn how various conditions and design limitations affect gas turbine performance. This information will include how the gas turbine develops and uses hot gases under pressure. You will also learn the nomenclature related to gas turbines and gas turbine technology. After reading this chapter, you will be able to describe the principal components of gas turbines and their construction.

HISTORY AND BACKGROUND

Until recent years it has not been possible to separate gas turbine technology and jet engine technology. The same people have worked in both fields, and the same sciences have been applied to both types of engines. Recently, the jet engine has been used more as a part of aviation. The gas turbine has been used for electric generation, ship propulsion, and even experimental automobile propulsion. Even now, many operational turbine power plants use an aircraft jet engine as a GG. A PT and transmission are added to complete the plant.

In nature, the squid was using jet propulsion long before our science thought of it. There were examples of the reaction principle in early history; however, practical application of the reaction principle has occurred only recently. This delay is due to slow progress of technical achievement in engineering, fuels, and metallurgy (the science of metals).

Between the first and third centuries A.D., lived Hero, a scientist in Alexandria, Egypt. He described what is considered to be the first jet engine. Many sources credit him as the inventor. True or not, a device, the aeolipile (figure 4-1), is mentioned in sources dating back as far as 250 B.C.

Throughout the course of history examples exist of other scientists using the principle of expanding gases to perform work. Among these were inventions of Leonardo da Vinci

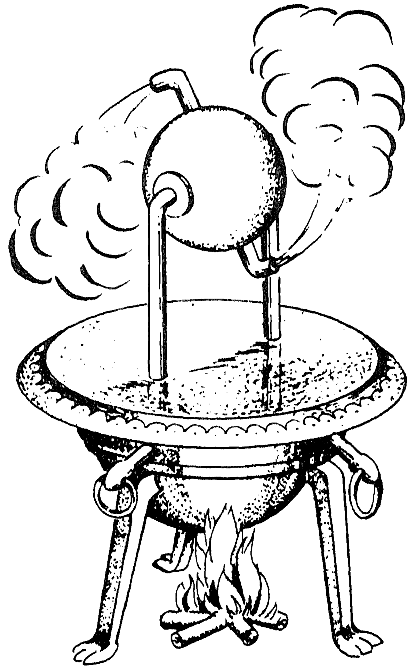

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Figure 4-1.—Hero's aeolipile.

(figure 4-2) and Giovanni Branca (figure 4-3).

In the 1680s Sir Isaac Newton described the laws of motion. All devices that use the theory of jet propulsion are based on these laws. Newton's steam wagon is an example of the reaction principle (figure 4-4).

The first patent for a design that used the thermodynamic cycle of the modern gas turbine was submitted in 1791. John Barber, an

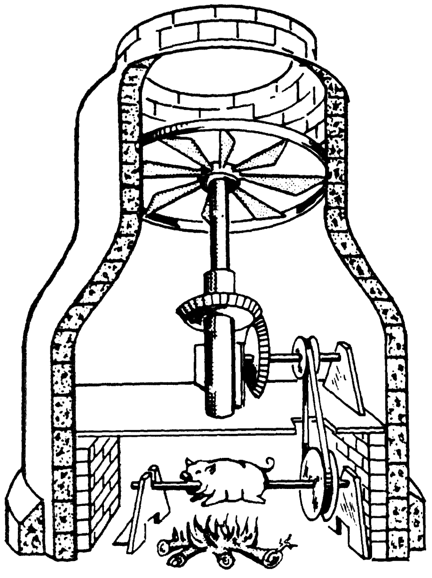

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Figure 4-2.—da Vinci's chimney jack.

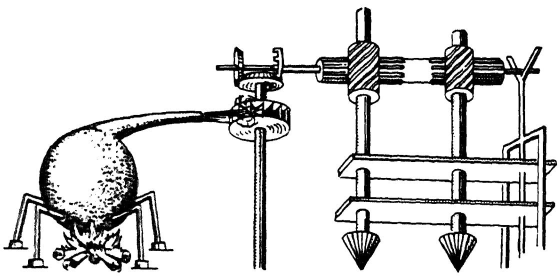

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Figure 4-3.—Branca's jet turbine.

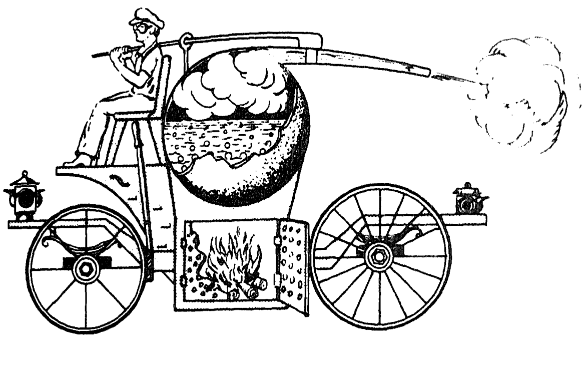

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Figure 4-4.—Newton's steam wagon.

Englishman, submitted the patent. It was also suggested as a means of jet propulsion.

TWENTIETH CENTURY DEVELOPMENT

The patented application for the gas turbine as we know it today was submitted in 1930 by another Englishman, Sir Frank Whittle. His patent was for a jet aircraft engine. Whittle used his own ideas along with the contributions of scientists such as Coley and Moss. After several failures, he came up with a working gas turbine engine (GTE). Up to this time the early pioneers in the gas turbine field were European born or oriented.

American Development

The United States did not go into the gas turbine field until late in 1941. General Electric was then awarded a contract to build an American version of a foreign-designed aircraft engine. The engine and airframe were both built in 1 year. The first jet aircraft was flown in this country in October 1942.

In late 1941 Westinghouse Corporation was awarded a contract to design and build the first all-American GTE. Their engineers designed the first axial flow compressor and annular combustion chamber. Both of these ideas, with minor changes, are the basis for the majority of contemporary engines in use today.

Marine Gas Turbines

The concept of using a gas turbine to propel a ship goes back to 1937. At that time a Pescara free piston gas engine was used experimentally with a gas turbine. The free piston engine, or gasifier (figure 4-5), is a form of diesel engine. It uses air cushions instead of a crankshaft to return the pistons. It was an effective producer of pressurized gases. The German navy used it in their submarines during World War II as an air compressor. In 1953 the French placed in service two small vessels powered by a free piston engine-gas turbine combination. In 1957 the liberty ship *William Patterson* went into service on a transatlantic run. It had six free piston engines driving two turbines.

At that time applications of the use of a rotary gasifier to drive a main propulsion turbine were used. The gasifier, or compressor, was usually an aircraft jet engine or turboprop front end. In 1947 the Motor Gun Boat 2009 of the British navy used a 2500-hp gas turbine. It was used to drive the center of three shafts. In 1951 the tanker *Auris*, in an experimental application, replaced one of four diesel engines with a 1200-hp gas turbine. In 1956 the *John Sergeant* had a very efficient installation. It gave a fuel consumption rate of .523 pounds per hp/hr. The efficiency was largely due to use of a regenerator which recovered heat from the exhaust gases.

By the late 1950s the gas turbine marine engine was becoming widely used, mostly by European navies. All the applications combined the gas turbine plant with another conventional form of

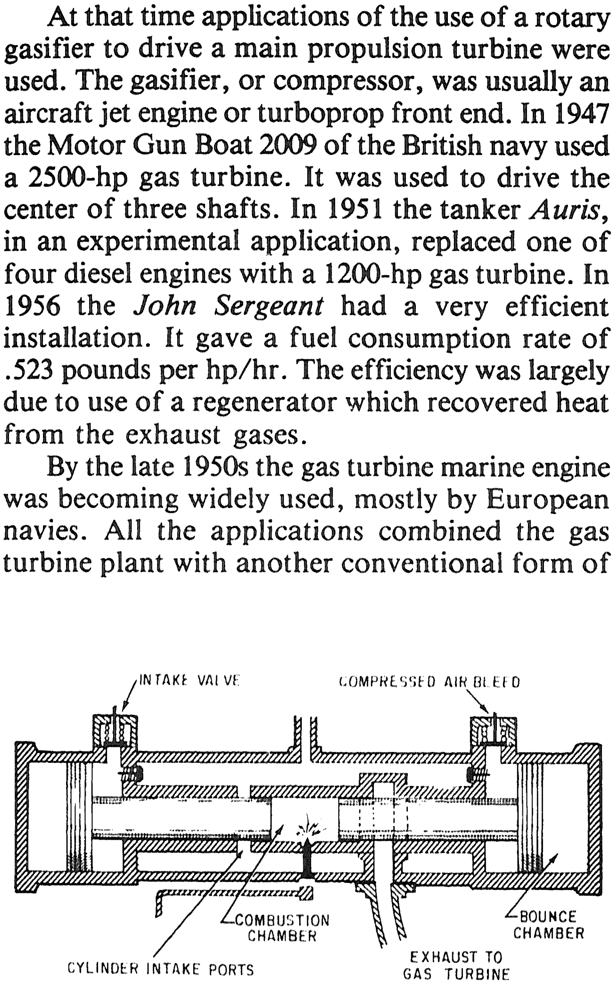

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Figure 4-5.—Free piston engine.

propulsion machinery. The gas turbine was used for high-speed operation. The conventional plant was used for cruising. The most common arrangements were the Combined Diesel or Gas (CODOG) or the Combined Diesel and Gas (CODAG) Systems. Diesel engines give good cruising range and reliability. But they have a disadvantage when used in antisubmarine warfare. Their low-frequency sounds travel great distances through water. This makes them easily detected by passive sonar. Steam turbines have been combined to reduce low-frequency sound in the Combined Steam and Gas (COSAG) configuration like those used on the British County class destroyers. However, these require more personnel to operate. Also they do not have the long range of the diesel combinations. Another configuration that has been successful is the Combined Gas or Gas (COGOG) such as used on the British type 42 DDG. These ships use the 4500-hp Tyne GTE for cruising. They use the Rolls Royce Olympus, a 28,000-hp engine, for high speed.

The U.S. Navy entered the marine gas turbine field with the *Asheville* class patrol gunboats. These ships have the CODOG configuration with two diesel engines for cruising. A General Electric LM1500 gas turbine operates at high speed. The Navy has now designed and is building destroyers, frigates, cruisers, and patrol hydrofoils that are entirely propelled by GTEs. This is a result of the reliability and efficiency of the new gas turbine designs.

ADVANTAGES AND DISADVANTAGES

The gas turbine, when compared to other types of engines, offers many advantages. Its greatest asset is its high power-to-weight ratio. This has made it, in the forms of turboprop or turbojet engine, the preferred engine for aircraft. Compared to the gasoline piston engine, the gas turbine operates on cheaper and safer fuel. The gasoline piston engine has the next best power-to-weight characteristics. The smoothness of the gas turbine, compared with reciprocating engines, has made it even more desirable in aircraft. Less vibration reduces strains on the airframe. In a warship, the lack of low-frequency vibration of gas turbines makes them preferable to diesel

engines. There is less noise for a submarine to pick up at long range. Modern production techniques have made gas turbines economical in terms of horsepower-per-dollar on initial installation. Their increasing reliability makes them a cost-effective alternative to steam turbine or diesel engine installation. In terms of fuel economy, modern marine gas turbines can compete with diesel engines. They may be superior to boiler/steam turbine plants, when these are operating on distillate fuel.

However, there are some disadvantages to gas turbines. Since they are high-performance engines, many parts are under high stress. Improper maintenance and lack of attention to details of procedure will impair engine performance. This may ultimately lead to engine failure. A pencil mark on a compressor turbine blade or a fingerprint can cause failure of the part. The turbine takes in large quantities of air which may contain substances or objects that can harm. Most gas turbine propulsion control systems are very complex because you have to control several factors. You have to monitor numerous operating conditions and parameters. The control systems must react quickly to turbine operating conditions to avoid casualties to the equipment. Gas turbines produce high-pitched loud noises which can damage the human ear. In shipboard installations special soundproofing is necessary. This adds to the complexity of the installation and makes access for maintenance more difficult. Also, the large amount of air used by a GTE requires large intake and exhaust ducting. This takes up much valuable space on a small ship.

From a tactical standpoint, there are two major drawbacks to the GTE. The first is the large amount of exhaust heat produced by the engines. Most current antiship missiles are heat-seekers. The infrared (IR) signature of a gas turbine makes an easy target. Countermeasures such as exhaust gas cooling and IR decoys have been developed to reduce this problem.

The second tactical disadvantage is the requirement for depot maintenance and repair of major casualties. The turbines are not overhauled in place on the ship. They must be removed and replaced by rebuilt engines if any major casualties occur. Here too, design has reduced the problem. An engine can be changed wherever crane service and the replacement engine are available.

FUTURE TRENDS

As improved materials and designs permit operation at higher combustion temperatures and pressures, gas turbine efficiency will increase. Even now, gas turbine main propulsion plants offer fuel economy and installation costs no greater than diesel engines. Initial costs are lower than equivalent steam plants which burn distillate fuels. Future improvements have made gas turbines the best choice for nonnuclear propulsion of ships up to cruiser size.

At present, marine gas turbines use aircraft jet engines for GGs. These are slightly modified for use in a marine environment, particularly in respect to corrosion resistance. As marine gas turbines become more widely used, specific designs for ships may evolve. These compressors may be heavier and bulkier than aircraft engines and take advantage of regenerators to permit greater efficiency.

Probably large gas turbines cannot be made simple enough to overhaul in place. So they will require technical support from shore. However, it is possible to airlift replacement engines. Gas turbine ships can operate and be repaired worldwide on a par with their steam- or diesel-driven counterparts.

The high power-to-weight ratios of GTEs permit the development of high-performance craft such as hydrofoils and surface effect vehicles. These crafts have high speed and are able to carry formidable weapons systems. They are being seen in increasing numbers in our fleet. In civilian versions, hydrofoils have been serving for many years to transport people on many of the world's waterways. Hovercraft are finding increased employment as carriers of people. They are capable of speeds up to 100 knots. If beach gradients are not too steep, they can reach points inland, marshy terrain, or almost any other level area.

GAS TURBINE OPERATION

A gas turbine engine is composed of three major sections:

1. Compressor(s)
2. Combustion chamber(s)
3. Turbine wheel(s)

A brief description of what takes place in a GTE during operation follows (figure 4-6). Air is taken in through the air inlet duct by the compressor which compresses the air and thereby raises pressure and temperature. The air is then discharged into the combustion chamber(s) where fuel is admitted by the fuel nozzle(s). The fuel-air mixture is ignited by igniter(s) and combustion takes place. Combustion is continuous, and the igniters are de-energized after a brief period of time. The hot and rapidly expanding gases are directed toward the turbine rotor assembly. Kinetic and thermal energy are extracted by the turbine wheel(s). The action of the gases against the turbine blades causes the turbine assembly to rotate. The turbine rotor is connected to the compressor which rotates with the turbine. The exhaust gases then are discharged through the exhaust duct.

About 75 percent of the power development by a GTE is used to drive the compressor and accessories. Only 25 percent can be used to drive a generator or to propel a ship.

LAWS AND PRINCIPLES

To understand basic engine theory, you must be familiar with the physics concepts used in the operation of a GTE. In the following paragraphs we will discuss the laws and principles that will apply to your work. We will define them, explain them, and then demonstrate how they apply to a gas turbine.

BERNOULLI'S PRINCIPLE: If an incompressible fluid flowing through a tube reaches a constriction, or narrowing of the tube, the velocity of fluid flowing through the constriction increases and the pressure decreases.

BOYLE'S LAW: The volume of an enclosed gas varies inversely with the applied pressure, provided the temperature remains constant.

CHARLES' LAW: If the pressure is constant, the volume of an enclosed dry gas varies directly with the absolute temperature.

NEWTON'S LAW: The first law states that a body at rest tends to remain at rest. A body in motion tends to remain in motion. The second law states that an imbalance of force on a body tends to produce an acceleration in the direction of the force. The acceleration, if any, is directly proportional to the force and inversely

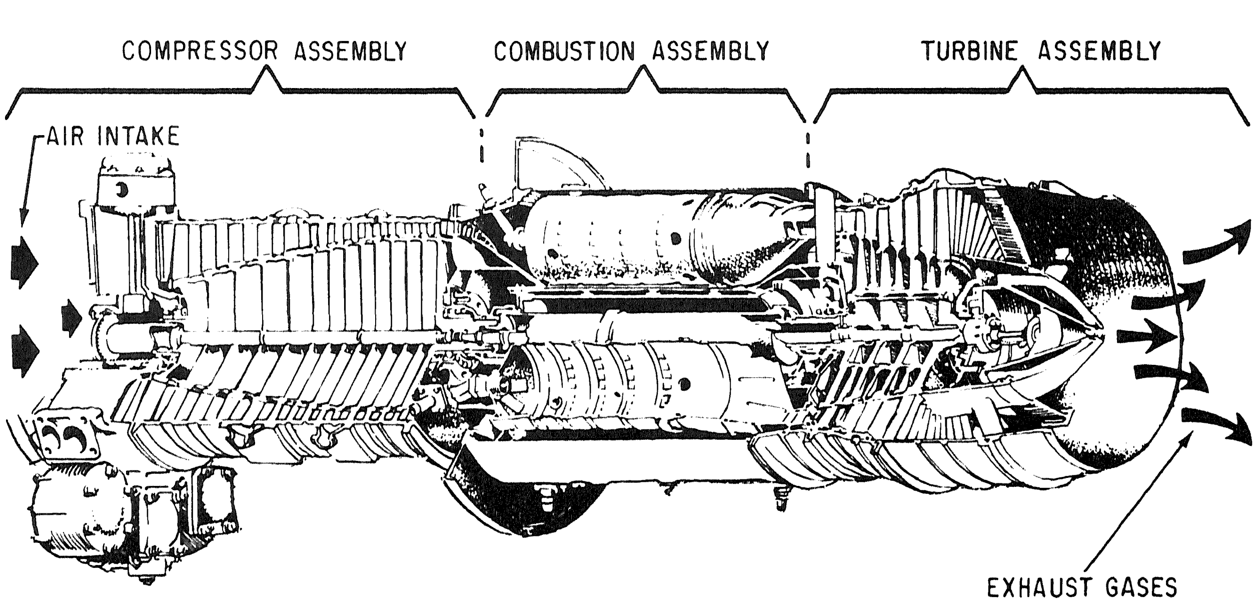

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Figure 4-6.—Gas turbine operation.

proportional to the mass of the body. Newton's third law states that for every action there is an equal and opposite reaction.

PASCAL'S LAW: Pressure exerted at any point upon an enclosed liquid is transmitted undiminished in all directions.

BERNOULLI'S PRINCIPLE

Consider the system illustrated in figure 4-7. Chamber A is under pressure and is connected by a tube to chamber B which is also under pressure. Chamber A is under static pressure of 100 psi. The pressure at some point, (X), along the connecting tube consists of a velocity pressure of 10 psi. This is exerted in a direction parallel to the line of flow. Added is the unused static pressure of 90 psi, which obeys Pascal's law and operates equally in all directions. As the fluid enters chamber B from the constricted space, it is slowed down. In so doing, its velocity head is changed back to pressure head. The force required to absorb the fluid's inertia equals the force required to start the fluid moving originally. Therefore, the static pressure in chamber B is again equal to that in chamber A. It was lower at intermediate point X.

The illustration (figure 4-7) disregards friction and is not encountered in actual practice. Force or head is also required to overcome friction. But, unlike inertia effect, this force cannot be recovered again although the energy represented still exists somewhere as heat. Therefore, in an actual system the pressure in chamber B would be less than in chamber A. This is a result of the amount of pressure used in overcoming friction along the way.

At all points in a system the static pressure is always the original static pressure LESS any velocity head at the point in question. It is also LESS the friction head consumed in reaching that point. Both velocity head and friction represent energy that came from the original static head. Energy cannot be destroyed. So, the sum of the static head, velocity head, and friction at any point in the system must add up to the original static head. This, then, is Bernoulli's principle, more simply stated: If a noncompressible fluid flowing through a tube reaches a constriction, or narrowing of the tube, the velocity of fluid flowing through the constriction increases, and the pressure decreases. Bernoulli's principle governs the relationship of the static and dynamic factors concerning noncompressible fluids. Pascal's law governs the behavior of the static factors when taken by themselves.

BOYLE'S LAW

Compressibility is an outstanding characteristic of gases. The English scientist, Robert Boyle, was among the first to study this characteristic. He called it the springiness of air. He discovered that when the temperature of an enclosed sample of gas was kept constant and the pressure doubled, the volume was reduced to half the former value. As the applied pressure was decreased, the resulting volume increased. From these observations he concluded that for a constant temperature the product of the volume and pressure of an enclosed gas remains constant. This became Boyle's law, which is normally

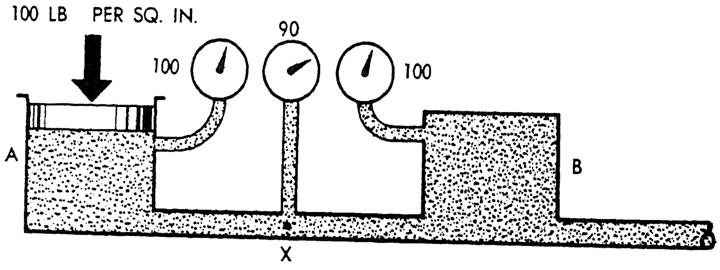

Figure 4-7.—Relation of static and dynamic factors—Bernoulli's principle.

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stated: The volume of an enclosed dry gas varies inversely with its pressure, provided the temperature remains constant.

You can demonstrate Boyle's law by confining a quantity of gas in a cylinder which has a tightly fitted piston. Then apply force to the piston so as to compress the gas in the cylinder to some specific volume. If you double the force applied to the piston, the gas will compress to one half its original volume (figure 4-8).

In formula or equation form (V = volume; P = pressure) when V_1 and P_1 are the original volume and pressure and V_2 and P_2 are the revised volume and pressure, this relationship may be expressed

$$V_1P_1 = V_2P_2$$

or

$$\frac{V_1}{V_2} = \frac{P_2}{P_1}$$

Example: 4 cubic feet of nitrogen are under a pressure of 100 psig. The nitrogen is allowed to expand to a volume of 6 cubic feet. What is the new gauge pressure? Remember to convert gauge pressure to absolute pressure by adding 14.7.

$$V_1P_1 = V_2P_2$$

Substitute

$$4 \times (100 + 14.7) = 6 \times P_2$$

$$P_2 = \frac{4 \times 114.7}{6}$$

$$P_2 = 76.47 \text{ psia}$$
(absolute pressure)

Convert absolute pressure to gauge pressure

$$\begin{array}{r} 76.47 \\ -\underline{14.7} \\ 61.77 \end{array}$$ psig (gauge pressure)

Changes in the pressure of a gas also affect the density. As the pressure increases, its volume decreases; however, there is no change in the weight of the gas. Therefore, the weight per unit volume (density) increases. So it follows that the density of a gas varies directly as the pressure, if the temperature is constant.

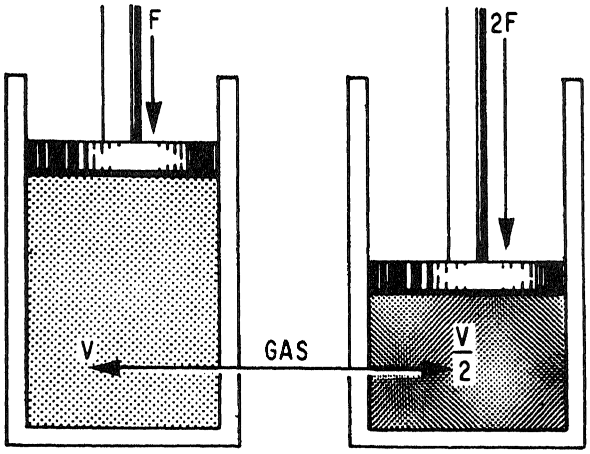

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Figure 4-8.—Gas compressed to half its original volume by a double force.

CHARLES' LAW

Jacques Charles, a French scientist, provided much of the foundation for the modern kinetic theory of gases. He found that all gases expand and contract in direct proportion to the change in the absolute temperature. This is provided the pressure is held constant. In equation form where V_1 and V_2 refer to the original and final volumes, and T_1 and T_2 indicate the corresponding absolute temperatures, this part of the law may be expressed

$$V_1T_2 = V_2T_1$$

or

$$\frac{V_1}{V_2} = \frac{T_1}{T_2}$$

Any change in the temperature of a gas causes a corresponding change in volume. Therefore, if a given sample of a gas were heated while confined within a given volume, the pressure should increase. Actual experiments found that for each

1 °C increase in temperature, the increase in pressure was about $\frac{1}{273}$ of the pressure at 0 °C. Thus, it is normal practice to state this relationship in terms of absolute temperature. In equation form, this part of the law becomes

$$P_1T_2 = P_2T_1$$

or

$$\frac{P_1}{P_2} = \frac{T_1}{T_2}$$

In words, this equation states that with a constant volume, the absolute pressure of an enclosed gas varies directly with the absolute temperature.

Examples of Charles' law: A cylinder of gas under a pressure of 1800 psig at 20 °C is left out in the sun. It heats up to a temperature of 55 °C. What is the new pressure within the cylinder? (You must convert the pressure and temperature to absolute pressure and temperature.)

$$\frac{P_1}{P_2} = \frac{T_1}{T_2}$$

or

$$\frac{1814.7 \text{ psia}}{2031.47 \text{ psia}} = \frac{293\,^{\circ}\text{C absolute}}{328\,^{\circ}\text{C absolute}}$$

NEWTON'S FIRST LAW

Newton's first law states that a body at rest tends to remain at rest. A body in motion tends to remain in motion. This law can be demonstrated easily in everyday use. For example, a parked automobile will remain motionless until some force causes it to move—a body at rest tends to remain at rest. The second portion of the law—a body in motion tends to remain in motion—can be demonstrated only in a theoretical sense. The same car placed in motion would remain in motion (1) if all air resistance were removed, (2) if no friction were in the bearings, and (3) if the surface were perfectly level.

NEWTON'S SECOND LAW

Newton's second law states that an imbalance of force on a body tends to produce an acceleration in the direction of the force. The acceleration, if any, is directly proportional to the force. It is inversely proportional to the mass of the body. This law can be explained by throwing a common softball. The force required to accelerate the ball to a rate of 50 ft/sec^2 would have to be doubled to obtain an acceleration rate of 100 ft/sec^2. However, if the mass of the ball were doubled, the original acceleration rate would be cut in half. You would have 50 ft/sec^2 reduced to 25 ft/sec^2. Do not confuse mass with weight. This law can be explained mathematically (A = acceleration; F = force; M = mass)

$$A = \frac{F}{M}$$

NEWTON'S THIRD LAW

Newton's third law states that for every action there is an equal and opposite reaction. You have demonstrated this law if you have ever jumped from a boat up to a dock or a beach. The boat moved opposite to the direction you jumped (figure 4-9).

The recoil from firing a shotgun is another example of action-reaction. We can demonstrate this law with the same factors used in the second law in the equation

$$F = MA$$

In an airplane, the greater the mass of air handled by the engine, the more it is accelerated by the engine. The force built up to thrust the plane forward is also greater. In a gas turbine, the thrust velocity can be absorbed by the turbine rotor and converted to mechanical energy. This is done by adding more and progressively larger PT wheels.

BASIC ENGINE THEORY

Two factors are required for proper operation of a gas turbine. One is expressed by Newton's third law. The other is the convergent-divergent

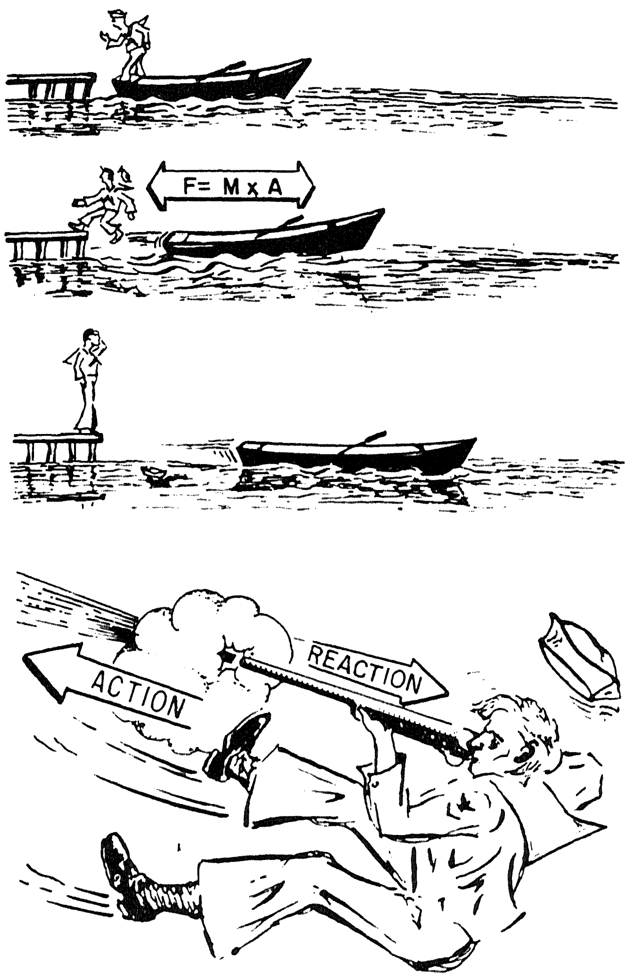

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Figure 4-9.—Newton's third law of motion.

process. Convergent means approaching nearer together, as the inner walls of a tube that is constricted. Divergent means moving away from each other, as the inner walls of a tube that flares outward.

Bernoulli's principle is used in this process. The venturi of the common automobile carburetor is a common example of Bernoulli's principle and the convergent-divergent process. The following is a description of a practical demonstration of how a gas turbine operates. (See figure 4-10, a foldout at the end of this chapter.)

A blown-up balloon (figure 4-10, item A) does nothing until the trapped air is released. The air escaping rearward causes the balloon to move forward (Newton's third law) (figure 4-10, item B).

If you could keep the balloon full of air, the balloon would continue to move forward (figure 4-10, item C).

If a fan or pinwheel is placed in the air stream, the pressure energy and velocity energy will cause it to rotate. It can then be used to do work (figure 4-10, item D).

Replace the balloon with a tube or container (mounted in one place). Fill it with air from a fan or series of fans. They should be located in the air opening and driven by some source. You use the discharge air to turn a fan at the rear to do work (figure 4-10, item E).

If fuel is added and combustion occurs, both the volume of air (Charles' law) and the velocity with which it passes over the fan are greatly increased. The horsepower the fan will produce is also increased (figure 4-10, item F).

The continuous pressure created by the inlet fan, or compressor, prevents the hot gases from going forward.

Next, if you attach a shaft to the compressor and extend it back to a turbine wheel, you have a simple gas turbine. It can supply power to run its own compressor and still provide enough power to do useful work. It could drive a generator or propel a ship (figure 4-10, item G).

By comparing figure 4-10, item H, with figure 4-10, item G, you can see that a gas turbine is very similar to the balloon turbine. Recall the three basic parts of a gas turbine mentioned earlier.

1. Air is taken in through the air inlet duct by the compressor. There it is raised in pressure and discharged into the combustion chamber.

2. Fuel is admitted into the combustion chamber by the fuel nozzle(s). The fuel-air mixture is ignited by igniter(s) and combustion occurs.

3. The hot and rapidly expanding gases are directed aft through the turbine rotor assembly. There thermal and kinetic energy are converted into mechanical energy. The gases are then directed out through the exhaust duct.

THEORETICAL CYCLES

Before we go into construction and design, we will discuss a little more on cycles and theory.

A cycle is a process that begins with certain conditions. It progresses through a series of additional conditions and returns to the original conditions.

The GTE operates on the BRAYTON CYCLE. The Brayton cycle is one where combustion occurs at constant pressure. In gas turbines specific components are designed to perform each function separately. These functions are intake, compression, combustion, expansion, and exhaust.

The Brayton cycle can also be graphically explained (figure 4-11). Air enters the inlet at atmospheric pressure and constant volume (point A). As the air passes through the compressor, it increases in pressure and decreases in volume (line A-B). At point B combustion occurs at constant pressure while the increased temperature causes a sharp increase in volume (line B-C). The gases at constant pressure and increased volume enter the turbine and expand through it. As the gases pass through the turbine rotor, the rotor turns kinetic and thermal energy into mechanical energy. The expanding size of the passages causes further increase in volume and a sharp decrease in pressure (line C-D). The gases are released through the stack with a large drop in volume and at constant pressure (line D-A). The cycle is continuous in a GTE, with each action occurring at all times.

OPEN AND CLOSED CYCLES

Most internal-combustion engines operate on an open engine cycle. This means the working fluid is taken in, used, and discarded. There are some gas turbines that operate on a semiclosed cycle. They use a regenerator such as used on the gas turbine ship *John Sergeant*. The gas turbines you will encounter in the Navy operate on the open cycle.

In the open cycle all the working fluid passes through the engine only once. The open cycle offers the advantages of simplicity and light weight.

The third classification of cycles is the closed cycle, where energy is added externally. The typical ship's steam plant is an example of a closed cycle system.

CONVERGENT-DIVERGENT PROCESS

There are several pressure, volume, and velocity changes that occur within a gas turbine during operation. The convergent-divergent process is an application of Bernoulli's principle. (If a fluid flowing through a tube reaches a constriction or narrowing of the tube, the velocity of the fluid flowing through the constriction increases and the pressure decreases. The opposite is true when the fluid leaves the constriction; velocity decreases and pressure increases.) Boyle's law and Charles' law also come into play during this process. Boyle's law: The volume of any dry gas varies inversely with the applied pressure, provided the temperature remains constant. Charles' law: If the pressure is constant, the volume of dry gas varies directly with the absolute temperature.

Now, let's apply these laws to the gas turbine. Refer to figure 4-12.

Air is drawn into the front of the compressor. The rotor is so constructed that the area decreases toward the rear. This tapered construction gives a convergent area (area A). Each succeeding stage is smaller, which increases pressure and decreases velocity (Bernoulli).

Between each rotating stage is a stationary stage or stator. The stator partially converts high velocity to pressure and directs the air to the next set of rotating blades.

Because of its high rotational speed, the rotor imparts velocity to the air. Each pair of rotor and stator blades constitutes a pressure stage. Also, there is both a pressure increase at each stage and a reduction in volume (Boyle).

This process continues at each stage until the air charge enters the diffuser (figure 4-12, area B). There is a short area in the diffuser where no further changes take place. As the air charge approaches the end of the diffuser, you will notice that the opening flares (diverges) outward. At this point, the air loses velocity and increases in volume and pressure. Thus, the velocity energy has become pressure energy, while pressure through the diffuser has remained constant. The reverse of Bernoulli's principle and Boyle's law has taken place. The compressor continuously forcing more air through this section at a constant rate maintains constant pressure. Once the air is in the combustor, combustion takes place

at constant pressure. After combustion there is a large increase in the volume of the air and combustion gases (Charles' law).

The combustion gases go rearward to area C. This occurs partially by velocity imparted by the compressor and partially because area C is a lower pressure area. The end of area C is the turbine nozzle section. Here you will find a decrease in pressure and an increase in velocity. The high-velocity, high-temperature, low-pressure gases are directed through the inlet nozzle to the first stage of the turbine rotor (area D). The high-velocity, high-temperature gases cause the rotor to rotate by transferring velocity energy and thermal energy to the turbine blades. Area D is a divergent area. Between each rotating turbine stage is a static stage or nozzle. The nozzles act much the same as the stators in the compressor.

A nozzle is a stator ring with a series of vanes. They act as small nozzles to direct the combustion gases uniformly and at the proper angle to the turbine blades. Due to the design of the nozzles, each succeeding stage imparts velocity to the gases as they pass through the nozzle. Each nozzle converts heat and pressure energy into velocity energy by controlling the expansion of the gas. Each small nozzle has a convergent area.

Each stage of the turbine is larger than the preceding one. The pressure energy drops are quite rapid; consequently, each stage must be larger to use the energy of a lower pressure, lower temperature, and larger volume of gases. If more stages are used the rate of divergence will be less. Area D must diverge rapidly in proportion to the rate in which area A converges into area B. Atmospheric air is raised in pressure and velocity and lowered in volume in area A by the

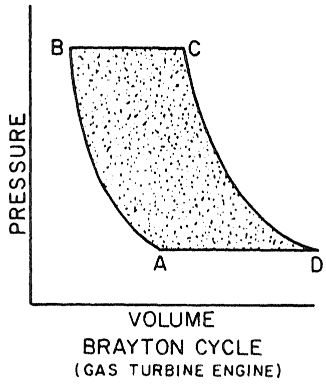

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Figure 4-11.—The Brayton cycle.

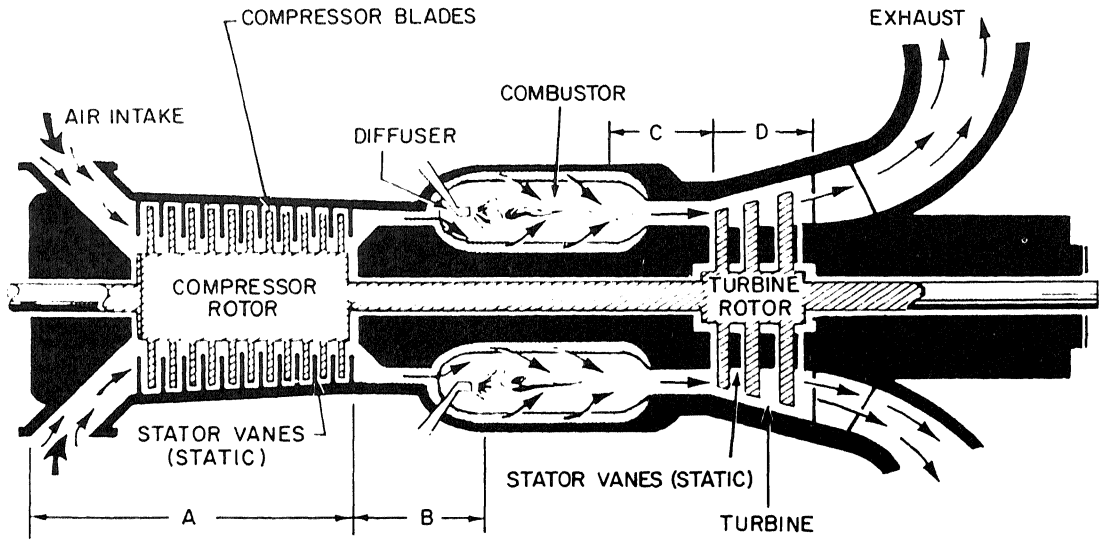

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Figure 4-12.—Convergent-divergent process.

compressor. Each stage can only compress air about 1.2 times, so the rate is limited. However, in the turbine rotor (area D), the gases give up thermal and pressure energy and increase in volume through three stages. (If this did not happen rapidly, back pressure from area D would cause area C to become choked.) The gases in the combustor would back up into the compressor. There they would disrupt airflow and cause a condition known as surge, or compressor stall. This condition can destroy an engine in a matter of seconds. Surge will be explained later in our discussion of axial flow compressors (stators).

The gases from the last turbine stage enter the exhaust duct where they are transmitted to the atmosphere. The leading portion of the exhaust duct is part of a divergent area. Further divergence reduces the pressure and increases the volume of the warm gases and aids in lowering the velocity. The exhaust gases enter the atmosphere at or slightly above atmospheric pressure. This depends on the length and size of the exhaust duct.

Now refer back to figure 4-11. Air enters the intake at constant pressure (point A). It is compressed as it passes through the compressor (line A-B in figure 4-11 and area A in figure 4-12). Between the end of area B and the beginning of area C in figure 4-12, combustion occurs and volume increases (figure 4-11, line B-C). As the gases pass through area D (figure 4-12), the gases expand with a drop in pressure and an increase in volume (figure 4-11, line C-D). The gases are discharged to the atmosphere through the exhaust duct at constant pressure (figure 4-11, line D-A and figure 4-12, exhaust). At this point you should have a clear understanding of how a simple gas turbine works.

ADIABATIC COMPRESSION

In the ideal gas turbine, the air enters the compressor and is compressed adiabatically. In an adiabatic stage change there is no transfer of heat to or from the system during the process. In many real processes, adiabatic changes can occur when the process is performed rapidly. Since heat transfer is relatively slow, any rapidly performed process can approach an adiabatic state. Compression and expansion of working fluids are often achieved almost adiabatically.

Figure 4-13 depicts the pressure-temperature graph for a simple gas turbine. During operation the work produced by the compressor turbine rotor is almost the same amount as the work required by the compressor. The mass flow available to the compressor turbine is about the same as the mass flow handled by the compressor. Therefore, the heat of compression will closely equal the heat of expansion. Allowances are made for factors such as bleed air, pressure of fuel added, and heat loss to turbine parts.

As the high-temperature, high-pressure gases enter the turbine section, they expand rapidly. There is relatively little change in temperature of the gases. The net power available from the turbine is the difference between the turbine-developed power and the power required to operate the compressor.

EFFECT OF AMBIENT TEMPERATURE

The power and efficiency of a GTE are affected by both outside and inside variables. Air has volume that is directly affected by its temperature. As the temperature decreases, the volume of air for a given mass decreases and its density increases. Consequently, the mass weight of the air increases which, in turn, increases efficiency. This happens because less energy is needed to achieve the same compression at the combustion chambers. Also cooler air causes lower burning temperatures. The resulting

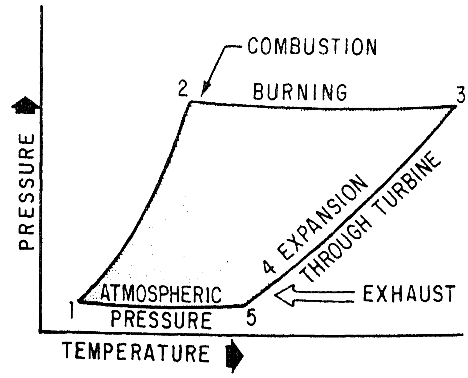

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Figure 4-13.—Gas turbine pressure-temperature relationship.

emperatures extend turbine life. For example, a ropulsion gas turbine is operating at 100 percent 3G speed with 100 percent PT speed. The mbient (external air) temperature is 70 °F. If the emperature were increased to 120 °F, the volume of air would increase. The mass weight would lecrease. Since the amount of fuel added is limited y the inlet temperature the turbine will withstand, he mass weight flow cannot be achieved; the esult is a loss of net power available for work. The plant may be able to produce only 90 to 95 percent of its rated horsepower.

On the other hand, if the ambient temperature vere to drop to 0 °F, the volume of air would lecrease. The mass weight would increase. Since he mass weight is increased and heat transfer is etter at higher pressure, less fuel is needed to ncrease volume; the result is a heavier mass of ir at the required volume. This situation produces quite an efficient power plant. It has a GG speed of 85 to 90 percent and a PT speed of 100 perent. In the case of a constant speed engine, the lifferences in temperature will show up on xhaust gas temperature. In some cases, it will how up on the load the engine will pull. For nstance, on a hot day of 120 °F, the engine on 300-kW generator set may be able to pull only 275 kW. This is due to limitations on exhaust or urbine inlet temperature. On a day with 0 °F mbient temperature, the same engine will pull 300-kW. It can have an exhaust or turbine inlet emperature that is more than 100 °F, lower than verage. Here again, less fuel is needed to increase olume and a greater mass weight flow. In turn, he plant is more efficient.

COMPRESSOR CLEANLINESS

Another factor that will have a great effect on performance is the condition of the compressor. A clean compressor is essential to efficiency and eliability. During operation at sea the compressor will ingest salt spray. Over a period of time, this alt will build up in the compressor. Salt buildup s relatively slow. It will occur more on the stator vanes and the compressor case than on rotating parts. Centrifugal force tends to sling salt conaminants off the rotor blades. Also, oil rapidly ncreases contamination of the compressor. Any oil ingested into the engine coats the compressor vith a film. The film traps any dust and other foreign matter suspended in the air. The dust and dirt absorb more oil which traps more dirt, and so forth. If left unattended, the buildup of contamination will lead to a choking of the compressor and a restricted airflow. In turn, gradually more fuel is required. So the gas temperatures will rise until loss of power and damage to the turbine may result. Contamination, if not controlled, can lead to a compressor surge during engine start. It will also reduce the life of the compressor and turbine blading.

TYPES OF GAS TURBINE ENGINES

There are several different types of gas turbines, all using the same basic principles already discussed. GTEs are classified by their construction (the type of compressor, combustor, or its shafting). The compressor may be either centrifugal or axial type. The combustor may be annular, can-annular, or can type. The type of shaft used on a GTE is also used to classify an engine. The three types are single shaft, split shaft, or twin spool. These classifications will be discussed on the following pages.

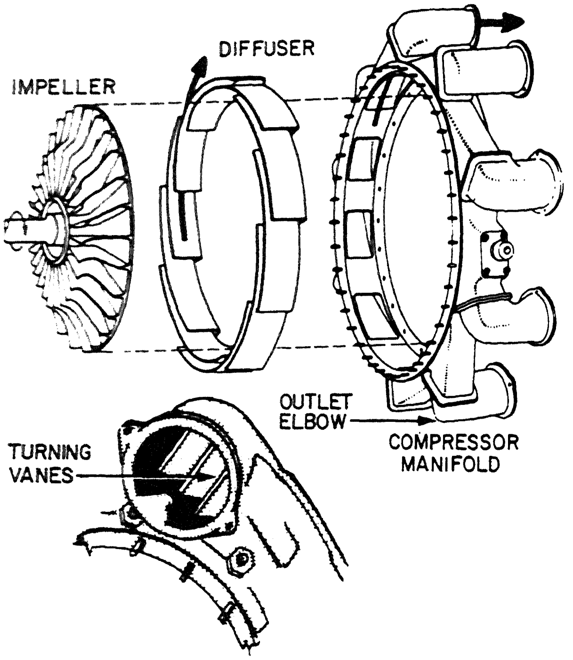
CLASSIFICATION BY COMPRESSOR TYPE

Gas turbines may be classified by compressor type, according to the direction of the flow of air through the compressor. The two principal types are centrifugal flow and axial flow. The centrifugal compressor draws in air at the center or eye of the impeller and accelerates it around and outward. In the axial flow engine the air is compressed while continuing its original direction of flow. The flow of air is parallel to the axis of the compressor rotor.

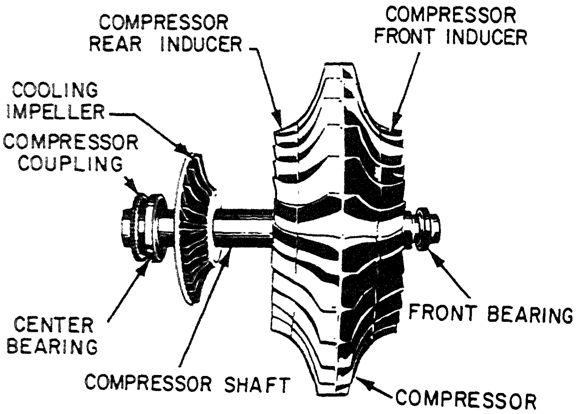
Centrifugal Compressor

The centrifugal compressor is usually located between the accessory section and the combustion section. The basic compressor section consists of an impeller, diffuser, and compressor manifold. The diffuser is bolted to the manifold. Often the entire assembly is referred to as the diffuser. For ease of understanding, we shall treat each unit separately.

The impeller may be either single entry or dual entry (figure 4-14). The main differences between the single entry and dual entry are the size of the impeller and the ducting arrangement. The single entry impeller permits convenient ducting directly to the inducer vanes. The dual entry uses a more complicated ducting to reach the rear side. Single entry impellers are slightly more efficient in receiving air. They must be of greater diameter to provide sufficient air which increases the overall diameter of the engine.



A. ELEMENTS OF A SINGLE ENTRY CENTRIFUGAL COMPRESSOR; AIR OUTLET ELBOW WITH TURNING VANES FOR REDUCING AIR PRESSURE LOSSES.



B. DUAL ENTRY COMPRESSOR

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Figure 4-14.—Centrifugal compressors.

Dual entry impellers are smaller in diameter. They rotate at higher speeds to ensure sufficient airflow. Most gas turbines of present-day design use the dual entry compressor to reduce engine diameter. The air must enter the engine at almost right angles to the engine axis. Because of this a plenum chamber is also required for dual entry compressors. The air must surround the compressor at positive pressure before entering the compressor to give positive flow.

PRINCIPLES OF OPERATION.—The compressor draws in the entering air at the hub of the impeller and accelerates it radially outward by means of centrifugal force through the impeller. It leaves the impeller at a high velocity low pressure and flows through the diffuser (figure 4-14, item A). The diffuser converts the high-velocity, low-pressure air to low velocity with high pressure. The compressor manifold diverts the flow of air from the diffuser, which is an integral part of the manifold, into the combustion chambers.

CONSTRUCTION.—In the centrifugal compressor the manifold has one outlet port for each combustion chamber. The outlet ports are bolted to an outlet elbow on the manifold (figure 4-14, item A). The outlet ports ensure that the same amount of air is delivered to each combustion chamber.

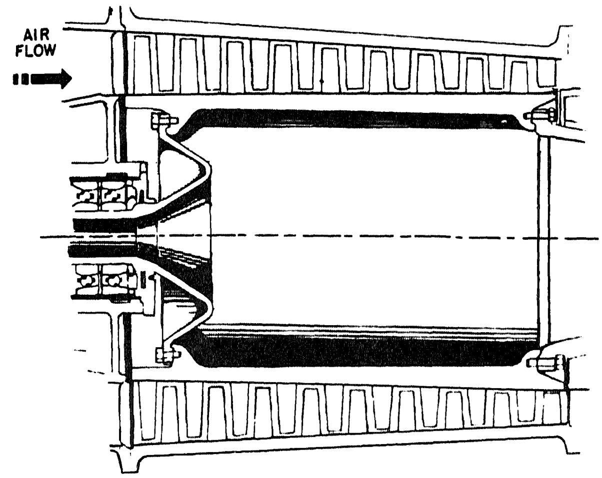
The outlets are known by a variety of names. Regardless of the names used, the elbows change the airflow from radial flow to axial flow. Then the diffusion process is completed after the turn. Each elbow contains from two to four turning vanes to efficiently perform the turning process. They also reduce air pressure losses by presenting a smooth turning surface.

The impeller is usually fabricated from forged aluminum alloy, heat-treated, machined, and smoothed for minimum flow restriction and turbulence. Some types of impellers are made from a single forging. In other types the inducer vanes are separate pieces.

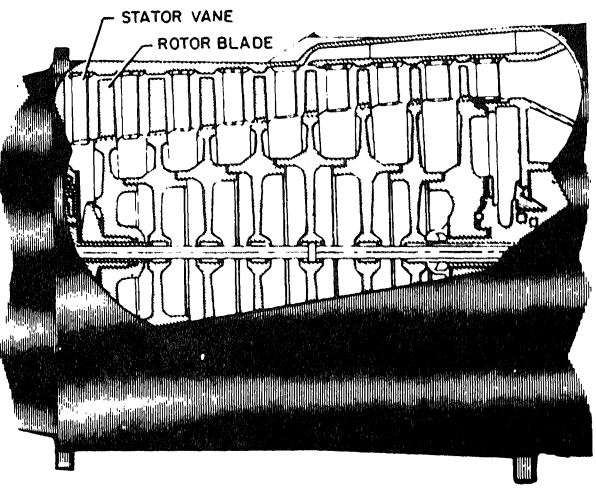
Centrifugal compressors may achieve efficien-ies of 80 to 84 percent at pressure ratios of 2.5:1 o 4:1 and efficiencies of 76 to 81 percent at ressure ratios of 4:1 to 10:1.

Advantages: rugged, simple in design, relative-y light in weight, and develops high-pressure ratio er stage.

Disadvantages: large frontal area, lower effi-iency, and difficulty in using two or more stages ue to air loss that will occur between stages and eals.



A. DRUM TYPE



B. DISK TYPE

203.25:26

Figure 4-15.—Compressor rotors.

Axial Flow Compressors

There are two main types of axial compressors (figure 4-15). One is the drum type and the other is the disk type.

The purpose of the axial compressor is the same as the centrifugal type. Both take in ambient air and increase the velocity and pressure. They discharge the air through the diffuser into the combustion chamber.

The two main elements of an axial flow compressor are the rotor and stator (figure 4-16).

The rotor has fixed blades which force the air rearward much like an aircraft propeller. Behind each rotor stage is a stator. The stator directs the air rearward to the next rotor stage. Each consecutive pair of rotor and stator blades constitutes a pressure stage.

The action of the rotor at each stage increases compression of the air at each stage and accelerates it rearward. By virtue of this

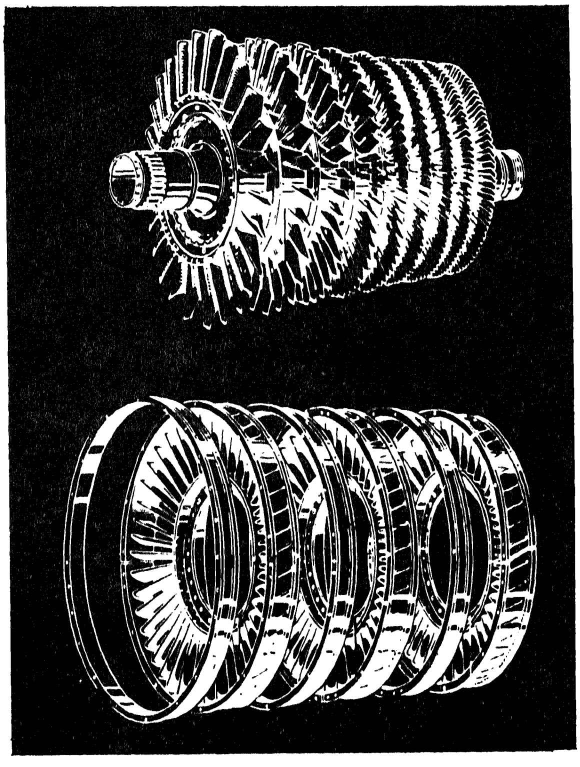


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Figure 4-16.—Rotor (top) and stator (bottom) components of an axial flow compressor.

increased velocity, energy is transferred from the compressor to the air in the form of velocity energy. The stators at each stage act as diffusers, partially converting high velocity to pressure.

The number of stages required is determined by the amount of air and total pressure rise required. The greater the number of stages, the higher the compression ratio. Most present-day engines have 8 to 16 stages, depending on air requirements.

COMPRESSOR CONSTRUCTION.—The rotor and stators are enclosed in the compressor case. Present-day engines use a case that is horizontally divided into upper and lower halves. The halves are normally bolted together with either dowel pins or fitted bolts. They are located at various points. They ensure proper alignment to each other and in relation to other engine assemblies. The other assemblies bolt to either end of the compressor case.

On some older design engines, the case is a one-piece cylinder open on both ends. The one-piece compressor case is simpler to manufacture; however, any repair or detailed inspection of the compressor rotor is impossible. The engine must be removed and taken to a shop. There it is disassembled for repair or inspection of the rotor or stators. On many engines with the split case, either the upper or lower case can be removed. The engine can remain in place for maintenance and inspection.

The compressor case is usually made of aluminum or steel. The material used will depend on the engine manufacturer and the accessories attached to the case. The compressor case may have external connections made as part of the case. These connections are normally used to bleed air during starting and acceleration or at low-speed operation.

Drum-Type Construction.—The drum-type rotor (figure 4-15, item A) consists of rings that are flanged to fit one against the other. The entire assembly may then be held together by through bolts. The drum is one diameter over its full length. The blades and stators vary in length from front to rear. The compressor case tapers accordingly. This type of construction is satisfactory for low-speed compressors where centrifugal stresses are low.

Disk-Type Construction.—The disk-type rotor (figure 4-15, item B) consists of a series of disks machined from aluminum forgings, shrunk over a steel shaft. Another method of rotor construction is to machine the disks and shaft from a single aluminum forging. Then bolt steel stub shafts on the front and rear of the assembly. This provides bearing support surfaces and splines for joining the turbine shaft. The blades vary in length from entry to discharge. This is due to a progressive reduction in the annular working space (drum to casing) toward the rear. The working space decreases because the rotor disk diameter increases. The disk-type rotors are used almost exclusively in all present-day, high-speed engines.

COMPRESSOR BLADING.—Each stage of an axial compressor consists of a set of rotor and stator blades. Stator blades may also be referred to as vanes. The construction of these blades is important to efficient operation of a gas turbine.

Rotor Blades.—The rotor blades are usually made of stainless or semistainless steel. Methods of attaching the blades in the rotor disk rims vary in different designs. They are commonly fitted into disks by either bulb (figure 4-17, item A) or fir-tree (figure 4-17, item B) type of roots. The blades are then locked by means of grub-screws, peening, lockwires, pins, or keys.

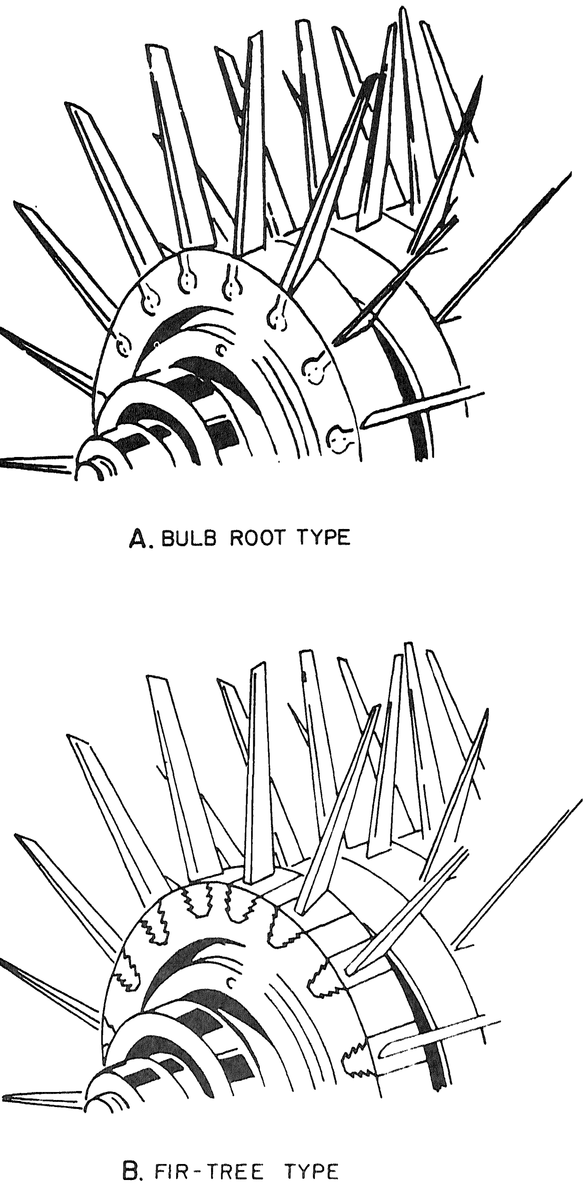
Compressor blade tips are reduced by cutouts, which are referred to as blade profiles. These profiles allow rubbing which occurs when rotor blades come into contact with the compressor or housing. This prevents serious damage to the blade or housing.

Some manufacturers use a ring that acts as a spacer for the stators. A ring can also act as a wear surface when the blade tips come into contact with the ring.

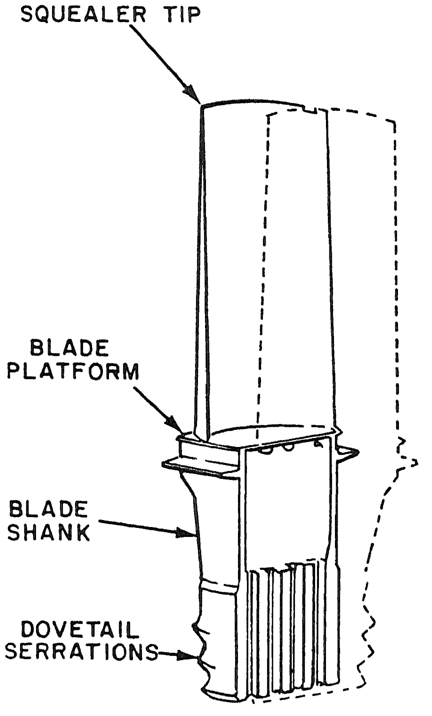
Another method of preventing excessive rubbing while maintaining minimum clearance is to metal-spray the case and stators. Thin squealer tips on the blades and vanes (figure 4-18) contact the sprayed material. The abrasive action of the blade tip prevents excessive rubbing while obtaining minimum clearance.

The primary causes of rubbing are an excessively loose blade or a malfunction of a compressor support bearing. This causes the compressor rotor to drop.

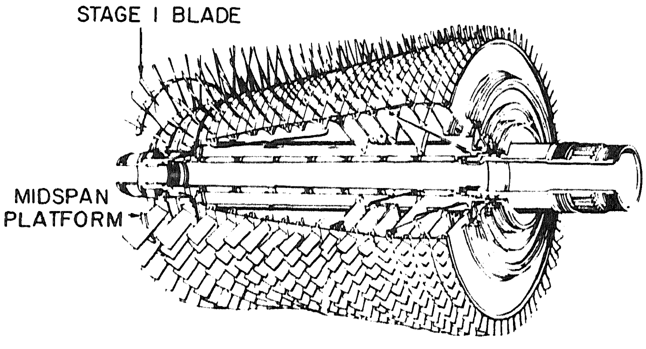
Large compressors have loose-fitting blades on the first several stages. These move during



203.24
Figure 4-17.—Rotor blades.



277.13
Figure 4-18.—Blade with squealer tip.



277.14
Figure 4-19.—Compressor rotor, LM2500 engine.

cceleration to minimize vibration while assing through critical speed ranges. Once p to speed, centrifugal force locks the blades place and little or no movement occurs. here is also movement of the blades during ndown. On a clean engine some of the blades ay have as much as 1/4-inch radial movement. You may hear a tinkling sound during ndown.

Large compressor rotors have long blades on the first stage. They have a piece made onto the blade called a midspan platform (figure 4-19). The platform gives some radial support to the blades during acceleration. Support is needed because of the length and amount of movement of the blades.

Stators.—The stator vanes project radially toward the rotor axis. They fit closely on either

side of each stage of the rotor. The function of the stators is twofold: (1) they receive air from the air inlet duct or from each preceding stage of the rotor. They then deliver the air to the next stage or to combustors at a workable velocity and pressure; (2) the stators also control the direction of air to each rotor stage to obtain the maximum possible compressor blade efficiency. The stator vanes are usually made of steel with corrosion- and erosion-resistant qualities. Frequently, the vanes are shrouded by a band of suitable material to simplify the fastening problem. The vanes are welded into the shrouds. The outer shrouds are secured to the inner wall of the compressor case by radial retaining screws.

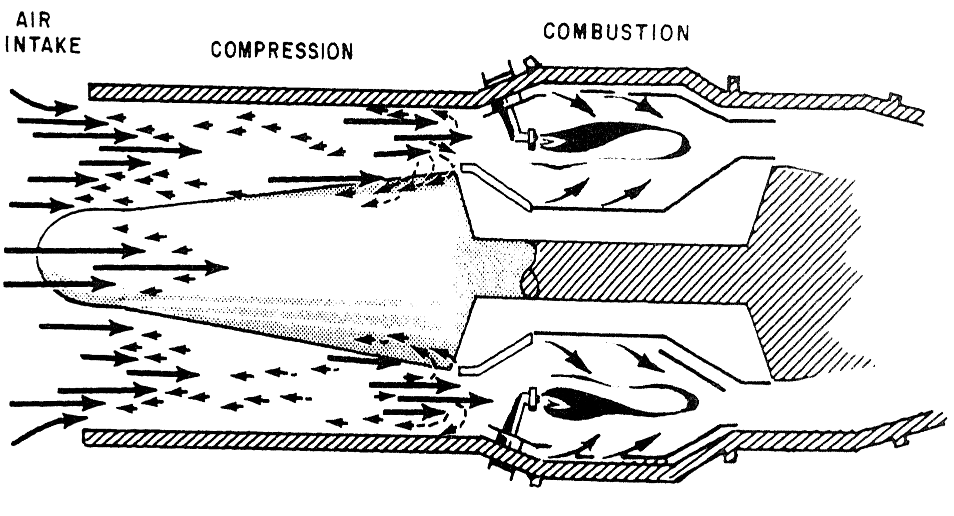
Some manufacturers machine a slot in the outer shrouds and run a long, thin key the length of the compressor case. The key is held in place by retaining screws to prevent the stators from turning within the case. This method is used when a one-piece compressor case is slid over the compressor and stator assembly.

Each pair of vanes in a stator acts as a diffuser. They use the divergent principle: the outlet of the vane area is larger than the inlet. This diverging area takes the high-velocity, low-pressure air from the preceding rotor stage. It converts it to a low-velocity, high-pressure airflow. Then it directs it at the proper angle to the next rotor stage. The next rotor stage will restore the air velocity that was lost because of the pressure rise. The next stator will give a further pressure rise. This process continues for each stage in the compressor.

A 1.2X-pressure rise is about as much as a single stage can handle. Higher pressure rises result in higher diffusion rates with excessive turning angles. This causes excessive air instability, hence low efficiency.

Preceding the stators and the first stage of the compressor is a row of vanes known as inlet guide vanes (IGVs). The function of the IGVs varies somewhat, depending on the size of the engine and the air-inlet construction. On smaller engines the air inlet is not totally in line with the first stage of the rotor. The IGVs straighten the airflow and direct it to the first-stage rotor. On large engines the IGVs are variable and move with the variable stators. The variable IGVs on large engines direct the airflow at the proper angle to reduce drag on the first-stage rotor. Variable IGVs achieve the same purposes as variable stator vanes (VSVs).

The variable stators are controlled by compressor inlet temperature (CIT) and engine power requirements. They are moved by mechanical linkages that are connected to the fuel-control governor. Variable stators have a twofold purpose: (1) they are positioned at various angles depending on compressor speed. They ensure the proper angle of attack between the compressor blades. Varying the blade angle helps to maintain maximum compressor efficiency over the



277.16

Figure 4-20.—Compressor surge.

perating speed range of the engine. This is nportant in variable speed engines such as those sed for main propulsion; (2) the variable stators n large engines virtually eliminate compressor irge. Surge (figure 4-20) results when the airflow alls across the compressor blades; that is, air is ot smoothly compressed into the combustion and irbine section. Stalling may occur over a few lades or a section of some stages. If enough flow interrupted, pressure may surge back through ie compressor. This occurrence can be minor or ery severe with possible damage to the turbine esulting.

All the air in the combustor then may be sed for combustion instead of only the primary r. Lack of cooling air may cause extreme emperatures which burn the combustor and turine section. (By a change in the angle of the ators and the use of bleed valves, the airflow rough the compressor is ensured. Compressor irge can be almost totally prevented.)

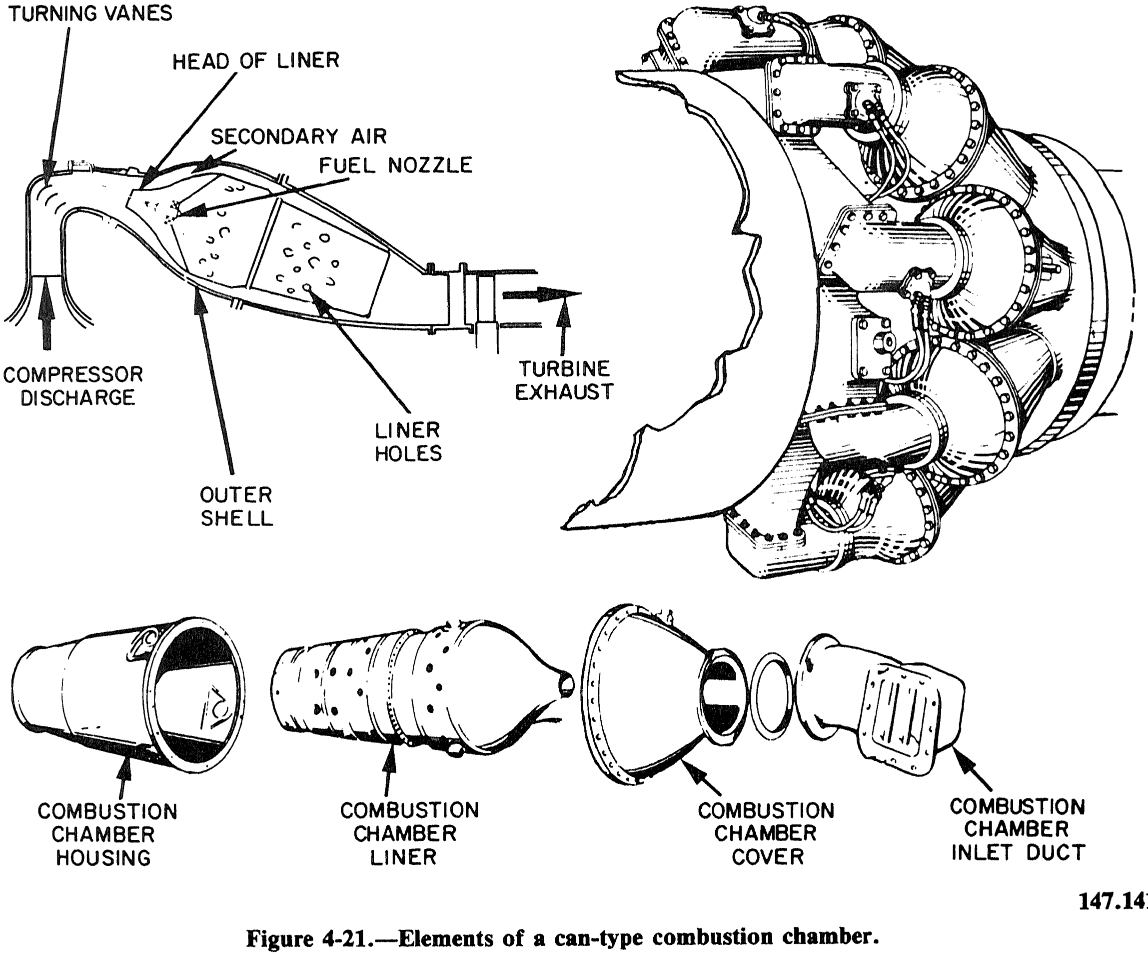
Constant-speed engines, such as those used to drive generators, normally do not use variable stators. They are designed to operate at 100-percent rpm all the time. The proper fuel schedule and bleed air valves are adequate to prevent or minimize compressor surge.

CLASSIFYING GAS TURBINES BY COMBUSTION CHAMBER DESIGN

There are three types of combustion chambers: (1) can type, (2) annular type, and (3) can-annular type. The can-type chamber is used primarily on engines that have a centrifugal compressor. The annular and can-annular types are used on axial flow compressors.

Can-Type Chamber

The can-type combustion system consists of individual liners and cases mounted around the axis of the engine. Each chamber (figure 4-21)



147.141:142

Figure 4-21.—Elements of a can-type combustion chamber.

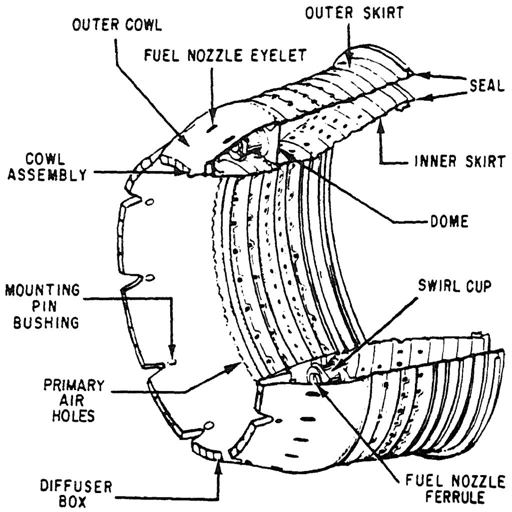
contains a fuel nozzle. This arrangement makes removing a chamber easy; however, it is a bulky arrangement and makes for a structurally weak engine. The outer casing is welded to a ring that directs the gases into the turbine nozzle. Each of the casings is linked to the others with a short tube. This arrangement ensures that combustion occurs in all the burners during engine start. Inside each of these tubes is a flame tube that joins an adjacent inner liner.

Annular-Type Chamber

The annular-type combustion chamber is usually found on axial flow engines. It is probably one of the most popular combustion systems in use. The construction consists of a housing and liner the same as the can type (figure 4-22).

The great difference is in the liner. On large engines, the liner consists of an undivided circular shroud extending all the way around the outside of the turbine shaft housing. A large one-piece combustor case covers the liner and is attached at the turbine section and diffuser section.

The dome of the liner has small slots and holes to admit primary air. They also impart a swirling motion for better atomization of fuel. There are also holes in the dome for the fuel nozzles to extend through into the combustion area. In the case of the double-annular chamber, two rows of fuel nozzles are required. The inner and outer liners form the combustion space. The outer liner keeps flame from contacting the combustor case. The inner liner prevents flame from contacting the turbine shaft housing.



277.19
Figure 4-22.—Annular-type combustion chamber.

Large holes and slots are located along the liners. They (1) admit some cooling air into the combustion space to help cool the hot gases to a safe level, (2) center the flame, and (3) admit the balance of air for combustion. The gases are cooled enough to prevent warpage of the liners.

The annular-type combustion chamber is a very efficient system that minimizes bulk. It can be used most effectively in limited space. There are some disadvantages, however. On some engines, the liners are one piece and cannot be removed without engine disassembly. Also, engines that use a one-piece combustor dome must be disassembled to remove the dome.

Can-Annular Type of Chamber

The can-annular type of combustion chamber combines some of the features of both the can and the annular burners.

The can-annular type of chamber design is a result of the split spool compressor concept. Problems were encountered with a long shaft and with one shaft within the other. Because of these problems a chamber was designed to perform all the necessary functions.

In the can-annular type of chamber individual cans are placed inside an annular case. The cans are essentially individual combustion chambers (figure 4-23) with concentric rings of perforated holes to admit air for cooling. On some models each can has a round perforated tube which runs down the middle of the can. The tube carries additional air which enters the can through the perforations to provide more air for combustion and cooling. The effect is to permit more burning per inch of can length than could otherwise be done.

Fuel nozzle arrangement varies from one nozzle in each can to several nozzles around the perimeter of each can.

The cans have an inherent resistance to buckling because of their small diameter. Each can has two holes which are opposite each other near the forward end of the can. One hole has

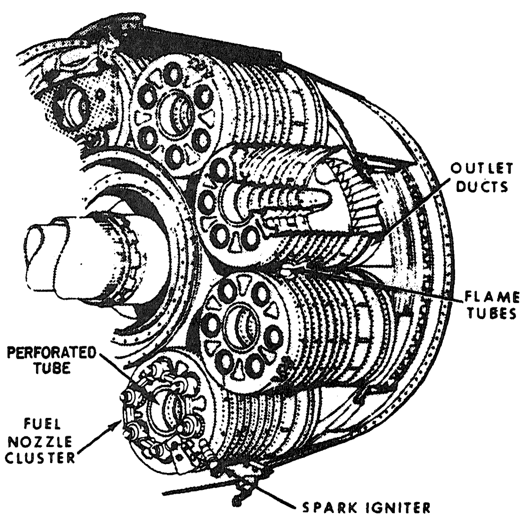


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Figure 4-23.—Can-annular type combustion chamber, components and arrangement.

a collar called a flame tube. When the cans are assembled in the annular case, these holes and their collars form open tubes. The tubes are between adjacent cans so that a flame passes from one can to the next during engine starting.

The short length of the can-annular type of chamber is a structural advantage. It provides minimal pressure drop of the gases between the compressor outlet and the flame area. Another advantage of the can-annular engine is the greater structural strength it gets from its short combustor area. Maintenance is also simple. You can just slide the case back and remove any one burner for inspection or repair. Another good feature is the relatively cool air in the annular outer can. It tends to reduce the high temperatures of the inner cans. At the same time, this air blanket keeps the outer shell of the combustion section cooler.

CLASSIFICATION OF GAS TURBINES BY TYPE OF SHAFTING

Several types of gas turbine shafts are used. These are SINGLE SHAFT, SPLIT SHAFT, and TWIN SPOOL. Of these, the single shaft and split shaft are the most common in use in naval vessels. We will mention the twin spool type and give a brief description. The USCG *Hamilton* class cutters use the Pratt-Whitney FT-4 twin spool gas turbine.

In current U.S. Navy service the single shaft engine is used primarily for driving ship's service generators. The split shaft engine is used for main propulsion as a variety of speed ranges is encountered.

Figure 4-24 is a block diagram of a single shaft gas turbine. In the engine illustrated, the power

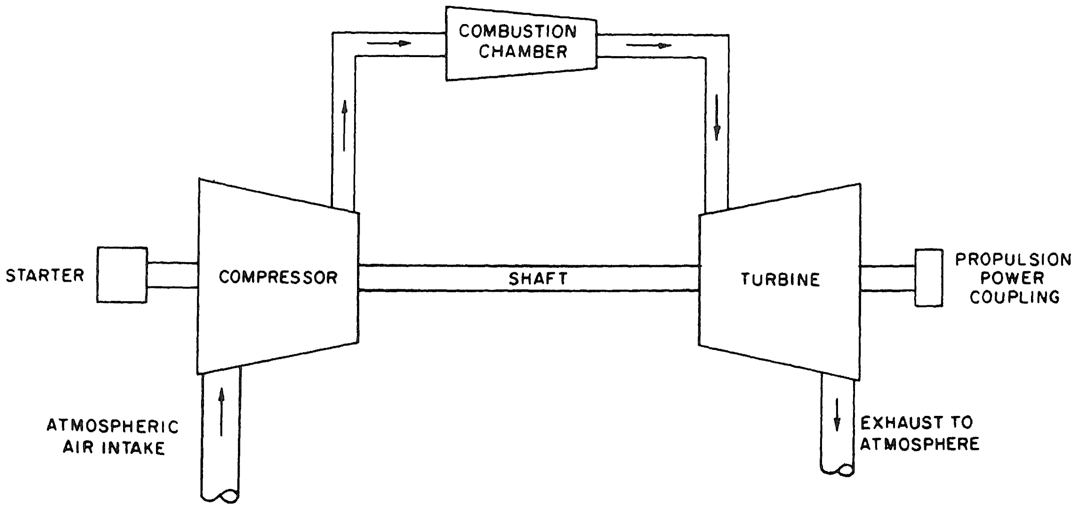

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Figure 4-24.—Single shaft engine.

output shaft is connected directly to the same turbine rotor that drives the compressor. In most cases, there is a speed decreaser or reduction gear between the rotor and the power output shaft; however, there is still a mechanical connection throughout the entire engine.

In the split shaft engine (figure 4-25), there is no mechanical connection between the GG turbine and the PT. With this type of engine the

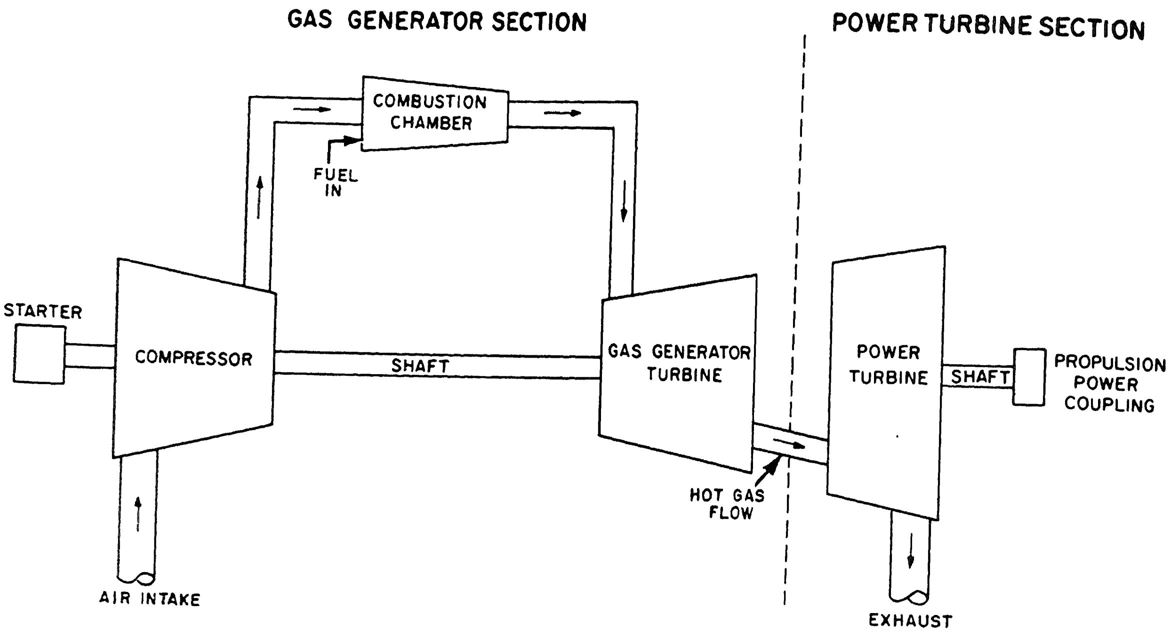

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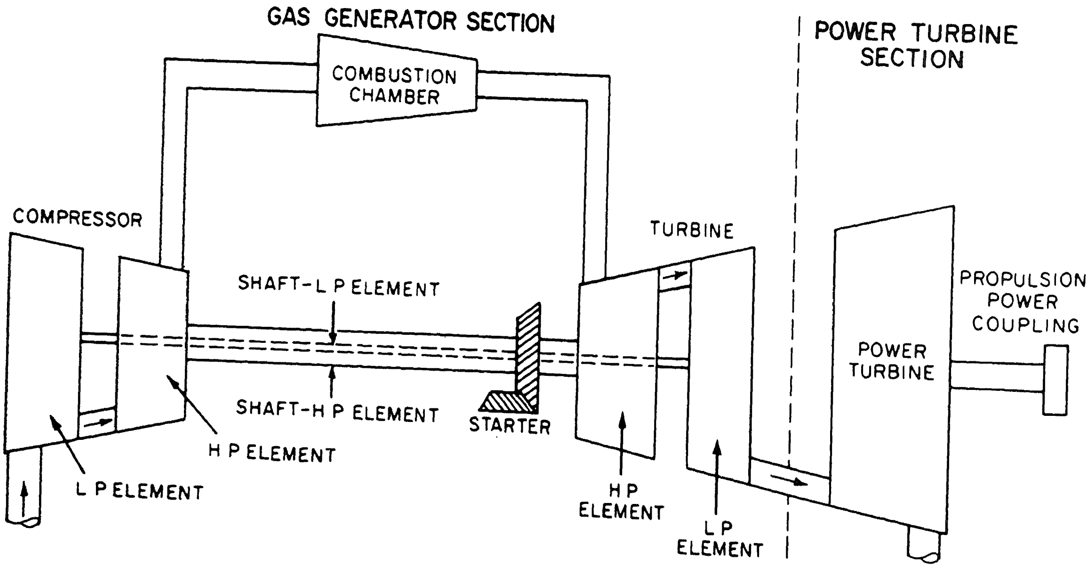
Figure 4-25.—Split shaft engine.



147.137

Figure 4-26.—Twin spool engine.

output speed can be varied by varying the generator speed. Also, under certain conditions, the GG can run at a reduced rpm and still provide maximum PT rpm. The reduced rpm greatly improves fuel economy and also extends the life of the GG turbine. The starting torque required is lowered. This is because the PT, reduction gears, and output shaft are stationary until the GG reaches approximate idle speed. Another feature is that in a multishaft marine propulsion plant the GG rotates only one way. One design (clockwise rotation or counterclockwise rotation) of the GG can be used on either shaft; however, the PT can be made to rotate either way. This is done by changing the PT wheel and nozzles. The arrangement shown in figure 4-25 is typical for propulsion gas turbines aboard the DD-963 and FFG-7 class ships.

Another type of turbine is the twin spool, sometimes referred to as a multistage gas turbine. In the twin spool engine there are two separate compressors and two separate turbine rotors. They are referred to as low-pressure (LP) compressor and turbine rotor and high-pressure (HP) compressor and turbine rotor (figure 4-26). The LP compressor and turbine are connected by a shaft. The shaft runs through the hollow shaft that connects the HP turbine to the HP compressor. The starter drives the HP assembly during engine start. The PT functions the same as in the split shaft engine. A larger volume of air can be handled as compared to a single or split shaft engine; however, the engine has more moving parts. The increase in overall dimensions and complexity makes the engine less desirable for ship's propulsion than the split shaft engine.

TURBINE ASSEMBLIES

Gas turbine engines are not normally classified by turbine type. We will discuss turbines now so you will understand their construction before covering specific engines in the next chapters.

In theory, design, and operating characteristics, the turbines used in GTEs are similar to those used in a steam plant. The gas turbine differs from the steam turbine chiefly in (1) the type of blading material used, (2) the means provided for cooling the turbine shaft bearings, and (3) the lower ratio of blade length to wheel diameter.

The terms GG turbine and PT are used to differentiate between the turbines. The GG turbine powers the GG and accessories. The PT powers the ship's propeller through the reduction gear and shafting.

The turbine that drives the compressor of a GTE is located directly behind the combustion chamber outlet. The turbine consists of two basic elements, the stator or nozzle, and the rotor. Part of a stator element is shown in figure 4-27; a rotor element is shown in figure 4-28.

Turbine Stators

The stator element of the turbine section is known by a variety of names. The three most

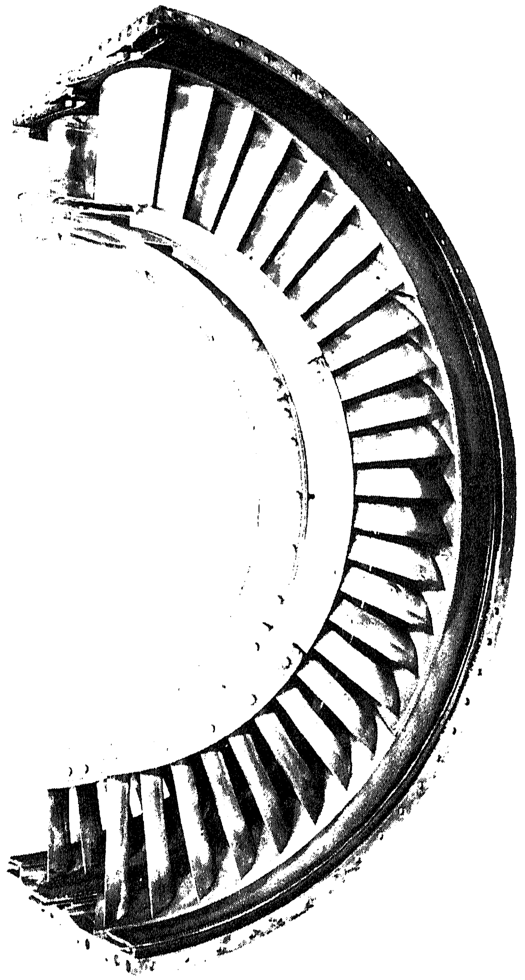


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Figure 4-27.—Cutaway of a turbine stator.

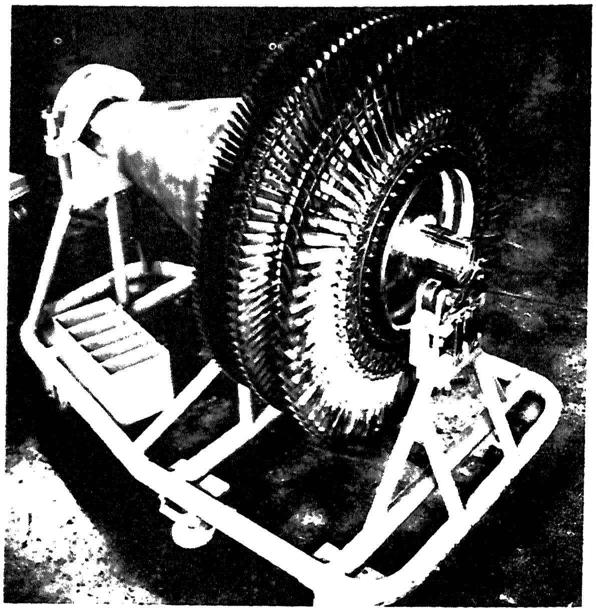

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Figure 4-28.—Turbine rotor elements.

common are turbine nozzle vanes, turbine guide vanes, and nozzle diaphragm. In this text, turbine stators are usually referred to as nozzles. The turbine nozzle vanes are located directly aft of the combustion chambers and immediately forward of, and between the turbine wheels.

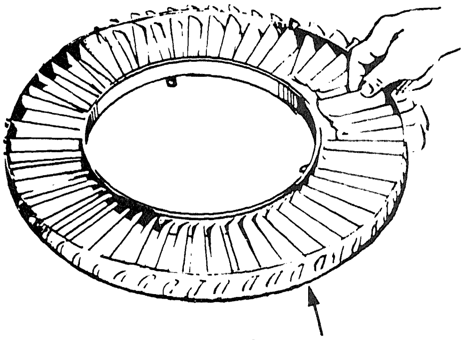
Turbine nozzles have a twofold function. First, the nozzles prepare the mass flow for harnessing of power through the turbine rotor. This occurs after the combustion chamber has introduced the heat energy into the mass airflow and delivered it evenly to the nozzles. The stationary vanes of the turbine nozzles are contoured and set at a certain angle. They form a number of small nozzles that discharge the gas as extremely high-speed jets; thus, the nozzle converts a varying portion of the heat and pressure energy to velocity energy. The velocity energy can then be converted to mechanical energy through the rotor blades.

The turbine nozzle functions to deflect the gases to a specific angle in the direction of turbine wheel rotation. The gas flow from the nozzle must enter the turbine blade passageway while it is still rotating. Therefore, it is essential to aim the gas in the general direction of turbine rotation.

The turbine nozzle assembly consists of an inner shroud and an outer shroud between which are fixed the nozzle vanes. The number of vanes varies with different types and sizes of engines. Figure 4-29 illustrates typical turbine nozzles featuring loose and welded vane fits.

The vanes of the turbine nozzle are assembled between the outer and inner shrouds or rings in different ways. Although turbine nozzles may differ in their construction, there is one characteristic special to all turbine nozzles; that is, the nozzle vanes must be constructed to allow for thermal expansion. Otherwise, rapid temperature variances could cause distortion or warping of the metal components.

Thermal expansion of turbine nozzles is accomplished by one of several methods. In one method the vanes are assembled loosely in the supporting inner and outer shrouds (figure 4-29, item A). Each of the vanes fits into a contoured slot in the shrouds. The slots conform with the airfoil shape of the vanes. These slots are slightly larger than the vane to give a loose fit. For further support the inner and outer shrouds are encased by an inner and an outer support ring.



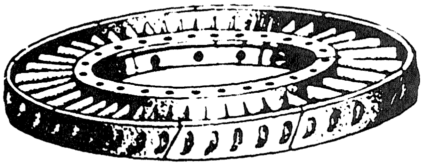


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Figure 4-29.—(A) Turbine nozzle vane assembly with loose-fitting vanes; (B) turbine nozzle vane assembly with welded vanes.

This adds strength and rigidity to the turbine nozzle. These supports also permit removal of the nozzle vanes as a unit; otherwise, the vanes could fall out of the shrouds as the shrouds are removed.

Another method to allow for thermal expansion is to fit the vanes into inner and outer shrouds. In this method the vanes are welded or riveted into position (figure 4-29, item B). Either the inner or the outer shroud ring is cut into segments to provide for thermal expansion. The saw cuts dividing the segments will allow enough expansion to prevent stress and warping of the vanes.

The basic types of construction of nozzles are the same for all types of turbines. The convergent-divergent principle (Bernoulli's principle) is used to increase gas velocity.

The turbine nozzles are made of high-strength steel. Steel can withstand the direct impact of the hot, high-pressure, high-velocity gases from the combustor. The nozzle vanes must also resist erosion from the high-velocity gases passing over them.

Increasing the inlet gas temperature by about 750 °F achieves almost a 100-percent increase in specific horsepower. However, nozzles do not stand up for long to the higher temperatures. Different methods of increasing nozzle endurance have been tried over the years.

One method that was tried was to coat the nozzle with a ceramic coating. Higher temperatures were achieved. However, the different expansion rates of the steel and the ceramic caused the coating to break away over a period of time. Experiments are still being conducted, even so far as to use an entirely ceramic nozzle.

Another means of withstanding high temperatures is to use newly developed alloys. However, extreme costs of the alloys prohibit commercial production of such nozzles.

Still another method, which is in wide use today in large engines, is to use air-cooled nozzle vanes. Compressor bleed air is fed through passages to the turbine where it is directed to the nozzle. The air cools both the turbine (discussed later) and the nozzle. The nozzle may also be cooled by air admitted from the outer perimeter of the nozzle ring. The method of getting the air in is determined by the manufacturer.

The nozzle vanes are made with many small holes or slots on the leading and trailing edges (figure 4-30). Air is forced into the nozzle and

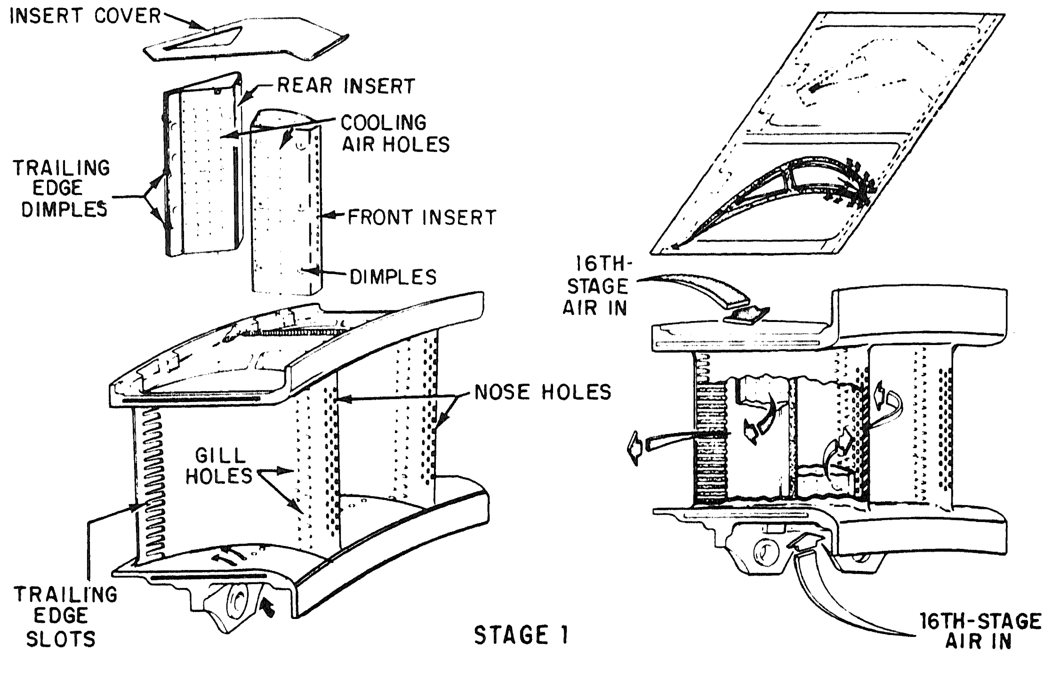

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Figure 4-30.—First-stage gas generator turbine nozzle cooling.

out through the slots and holes. The vane is cooled as the air passes through. The air is discharged into the hot gas stream, passing through the remainder of the turbine section. Then it passes out the exhaust duct.

Figure 4-31 compares temperature of an air-cooled vane against a nonair-cooled vane.

Cooling air is used primarily in the HP turbine section. The temperature of the gases is at an acceptable level by the time the gases reach the LP turbine section. In this section metals in current usage will last for long periods of time.

Seals installed between the nozzle entrance shroud and the turbine shaft may be pressurized with bleed air. This helps to minimize interstage leakage of the gases as they pass through the turbine.

Turbine Rotors

The rotor element of the turbine consists of a shaft and bladed wheel(s). The wheel(s) are attached to the main power transmitting shaft of the GTE. The jets of combustion gas leaving the vanes of the stator element act upon the turbine blades. Thus the turbine wheel can rotate in a speed range of about 3600 to 42,000 rpm. The high rotational speed imposes severe centrifugal loads on the turbine wheel. At the same time the high temperature (1050° to 2300°F) results in a lowering of the strength of the material.

Consequently, the engine speed and temperature must be controlled to keep turbine operation within safe limits. The operating life of the turbine blading usually determines the life of the GTE.

The turbine wheel is a dynamically balanced unit consisting of blades attached to a rotating disk. The disk in turn is attached to the rotor shaft of the engine. The high-velocity exhaust gases leaving the turbine nozzle vanes act on the blades of the turbine wheel. This causes the assembly to rotate at a very high rate of speed.

The turbine disk is referred to as such when in an unbladed form. When the turbine blades are installed, the disk then becomes the turbine wheel. The disk acts as an anchoring component for the turbine blades. The disk is bolted or welded to the shaft. This enables the blades to transmit to the rotor shaft the energy they extract from the exhaust gases.

The disk rim is exposed to the hot gases passing through the blades and absorbs considerable heat from these gases. In addition, the

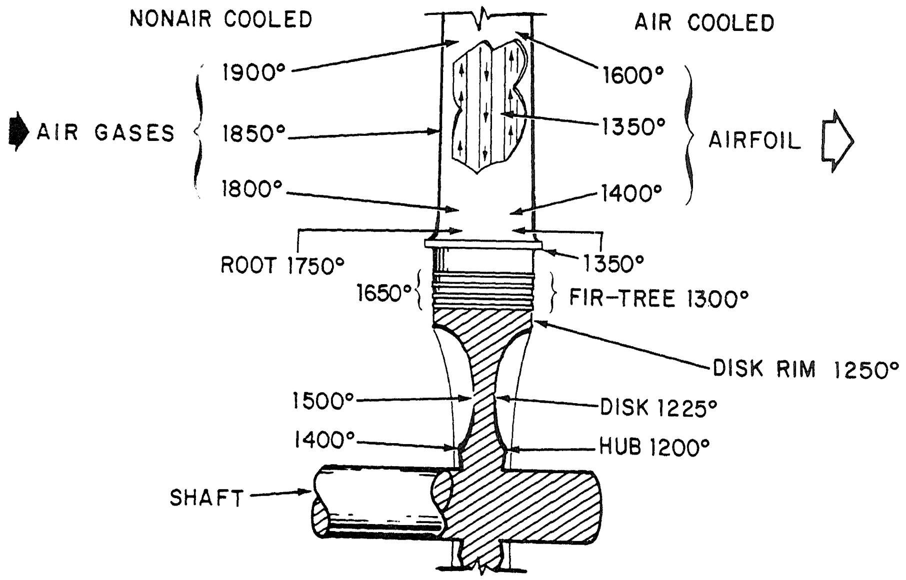

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Figure 4-31.—Cooling comparisons between an air-cooled vane and a nonair-cooled vane.

rim also absorbs heat from the turbine blades by conduction. Hence, disk rim temperatures normally are high and above the temperatures of the remote inner portion of the disk. As a result of these temperature gradients, thermal stresses are added to the stresses caused by rotation.

Various means are provided to relieve, at least partially, the stresses. One way is to incorporate an auxiliary fan somewhere ahead of the disk, usually rotor shaft-driven. This will force cooling air back into the face of the disk.

Another method of relieving the thermal stresses of the disk follows as incidental to blade installation. By notching the disk rims to conform with the blade root design, the disk is made able to retain the turbine blades. Also space is provided by the notches for thermal expansion of the disk.

The turbine shaft is usually made from low-alloy steel. It must be capable of absorbing high torque loads, such as exerted when a heavy axial flow compressor is started.

The methods of connecting the shaft to the turbine disk vary. One method used is welding. The shaft is welded to the disk, which has a butt or protrusion provided for the joint. Another method is by bolting. This method requires that the shaft have a hub which matches a machined surface on the disk face. The bolts then are inserted through holes in the shaft hub. They are anchored in tapped holes in the disk. Of the two methods, the latter is more common.

The turbine shaft must have some means for joining the compressor rotor hub; this is usually accomplished by making a splined cut on the forward end of the shaft. The spline fits into a coupling device between the compressor and the turbine shafts. If a coupling is not used, the splined end of the turbine shaft fits into a splined recess in the compressor rotor hub. The centrifugal compressor engines use the splined coupling arrangement almost exclusively. Axial compressor engines may use either of these described methods.

There are various ways of attaching turbine blades. Some ways are similar to the way compressor blades are attached. The most satisfactory method used is the fir-tree design shown in figure 4-32.

The blades are retained in their respective grooves by a variety of methods. Some of the more common methods are peening, welding, locking tabs, and riveting. Figure 4-33 shows a typical turbine wheel using riveting for blade retention.

The peening method of blade retention is often used. Its use may be applied in various ways. Two of the most common applications of peening are described in the following paragraphs.

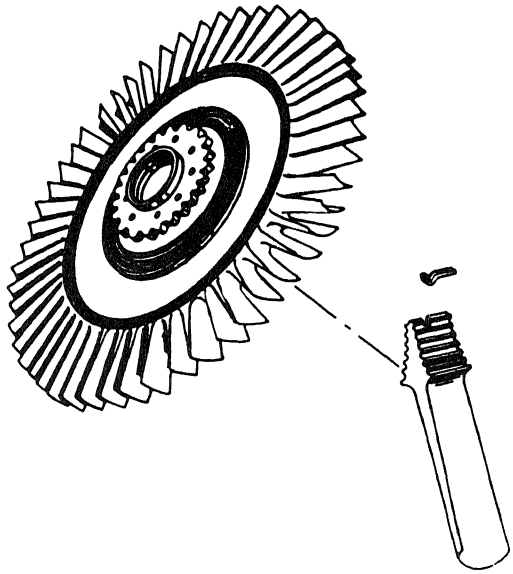

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Figure 4-32.—Turbine blade with fir-tree design and tab lock method of blade retention.

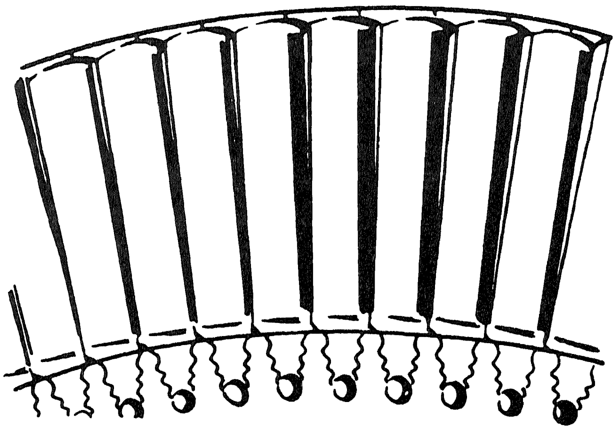

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Figure 4-33.—Riveting method of turbine blade retention.

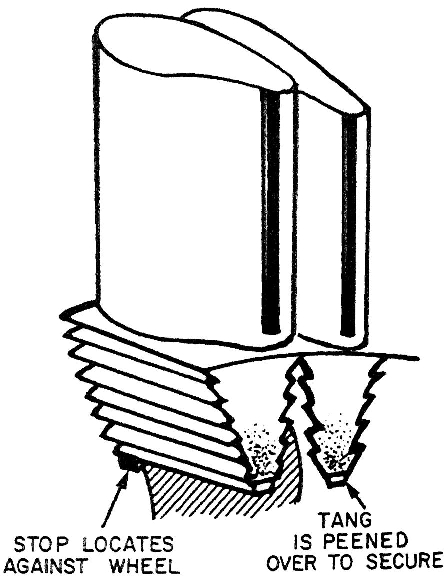

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Figure 4-34.—Turbine blade featuring peening method of blade retention.

One peening method requires you to grind a small notch in the edge of the blade fir-tree root. You do this before installing the blade. After you have installed the blade in the disk, the notch will fill with the disk metal. The disk metal is flowed into it through a small punchmark made in the disk adjacent to the notch. The tool you use for this job is similar to a centerpunch and is usually manufactured locally.

Another peening method is to construct the root of the blade so it contains the necessary retention elements. This method (figure 4-34) shows that the blade root has a stop made on one end of the root. The blade may be inserted and removed in one direction only. On the opposite end is a tang. You peen this tang over to secure the blade in the disk.

Turbine blades may be either forged or cast, depending on the metal they are made of. Turbine blades are usually machined from individual forgings. Various materials are used in the forging. Speed and operating temperatures are important factors that decide which materials go into the turbine blades.

Large engines use an air-cooled blading arrangement on the GG turbine (figure 4-35). Compressor discharge air is constantly fed through passages along the forward turbine shaft

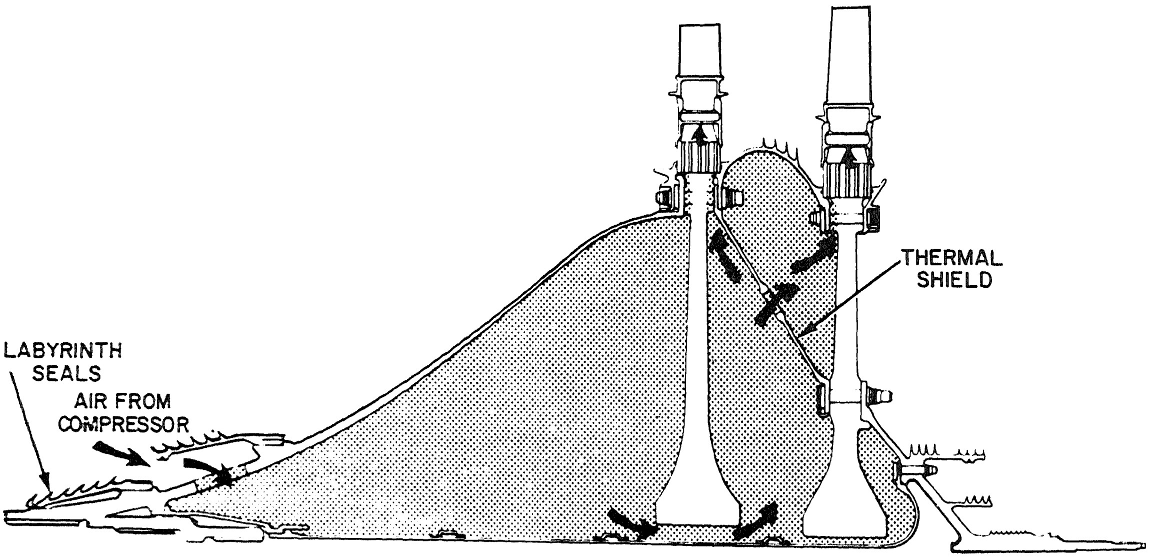

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Figure 4-35.—Gas generator turbine rotor cooling airflow.

between a spacer and the shaft. A thermal shield directs the cooling air along the face of the disk for cooling of the disk. The shield is between the first- and second-stage turbine wheels. The air is then directed through slots in the fir-tree portion of the disk, into slots in the blade fir-tree. The air then goes up through holes in the blades to cool the blades (figure 4-36).

Cooling of the turbine wheel and blades reduces thermal stresses on the rotating members. The turbine nozzles are also air cooled. By cooling the stationary and rotating parts of the turbine section, higher turbine inlet

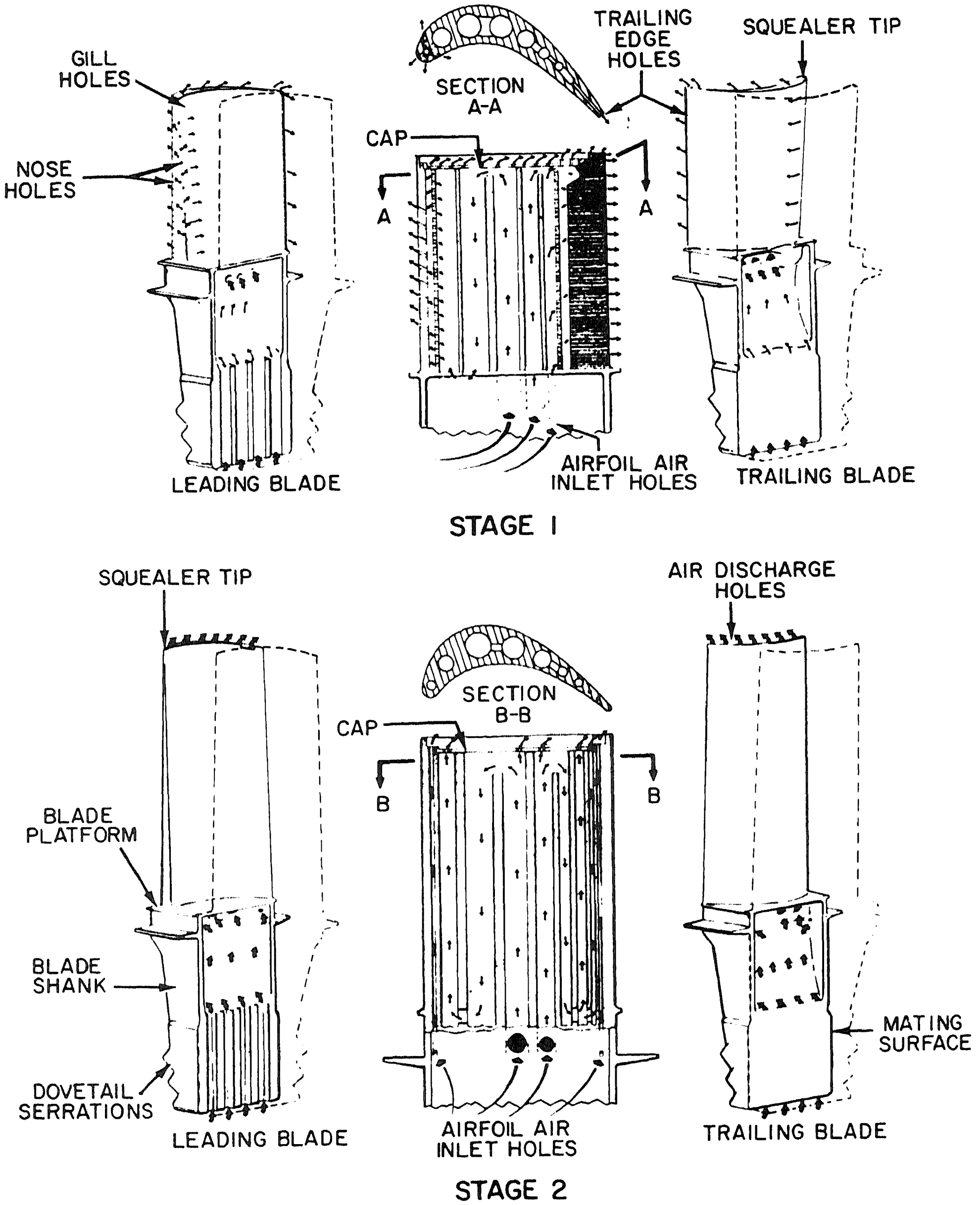

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Figure 4-36.—Gas generator turbine rotor blade cooling.

temperatures are permissible. The higher temperatures allow for more power, a more efficient engine, and longer engine life.

POWER TURBINES

Power turbines are used to extract the remaining energy from the hot gas. Power turbine wheels are used three different ways.

1. The aircraft jet turbine is designed so the turbine extracts only enough energy from the gases to run the compressor and accessories.
2. In the solid-wheel turbine, as much energy as possible is extracted from the gases to turn the turbine. The turbine provides power for the

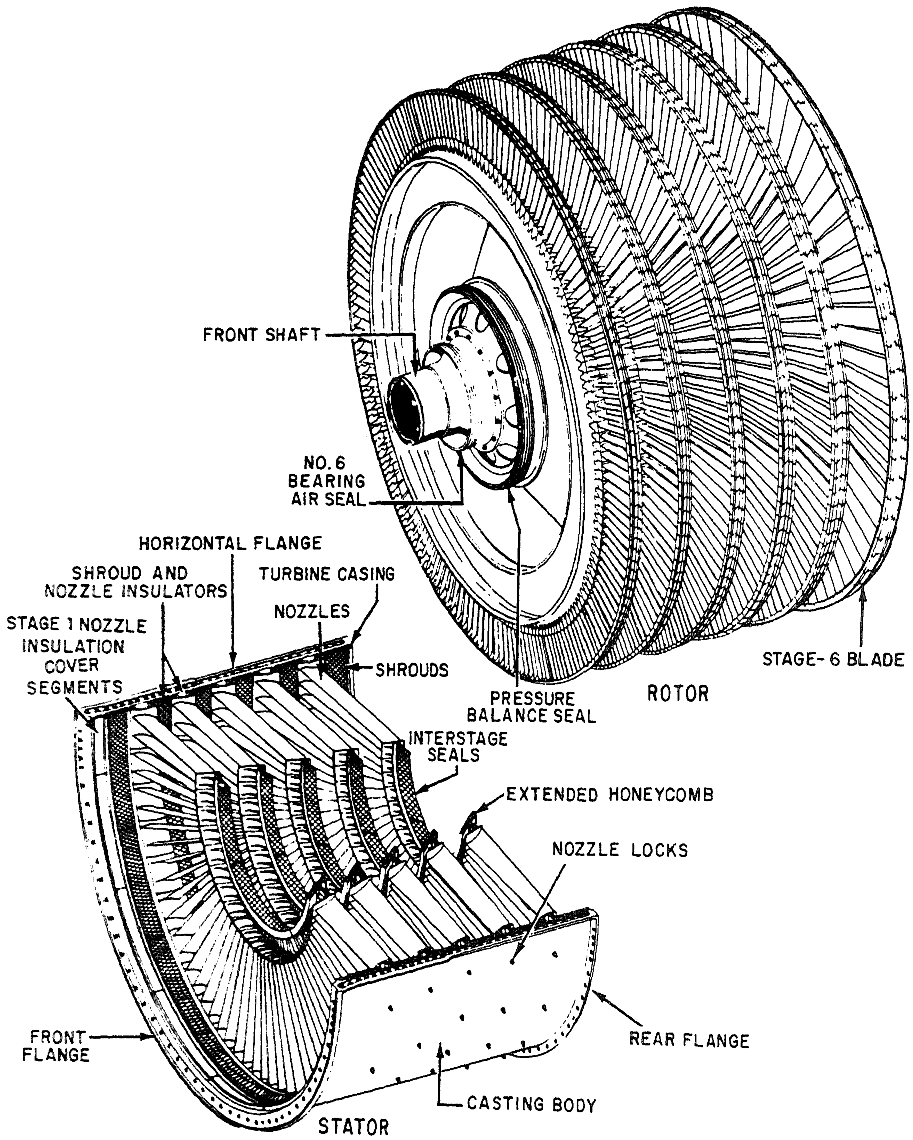

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Figure 4-37.—Typical power turbine.

compressor, accessories, and the airplane propeller or the ship's generator. Examples of these engines are a turboprop airplane or ship's service generator engine. These engines are designed to run at 100 percent specified rpm all the time. The location of the mechanical connection between the turbine wheel and the reduction gear on the compressor front shaft depends on the design of the installation. Normally, a ship's service generator cannot be disconnected from its gas turbine except by disassembly. This setup is used for generators to prevent slippage between the engine and the generator.

3. Marine propulsion engines use a combination of the two engine types. The GG has a single or dual stage high-pressure rotor that drives the compressor and accessories.

The PT (figure 4-37) is a multistage turbine located behind the GG turbine. There is no mechanical connection between the two turbines. The PT is connected to a reduction gear through a clutch mechanism. Either a controllable reversible pitch propeller or a reverse gear is used to change direction of the vessel.

Some ships that have two sets of engines use counterrotating PTs. For example, PTs on one shaft rotate clockwise while the turbines on the other rotate counterclockwise. This arrangement eliminates the use of a V-drive. The GG portion rotates in the same direction for both sets of engines. The blade angle of the wheel and the nozzles in the PT section determine the directional rotation of the PT. On large ships where different length propeller shafts are permitted, the engine(s) can be mounted to the other end of the reduction gear. In this way counterrotation of the propellers is achieved.

By varying the GG speed, the output speed of the PT can be controlled. Since only a portion of the energy is used to drive the compressor, the plant can be operated very efficiently. For example, on a cold day you can have 100 percent power turbine rpm with 80 to 90 percent gas generator rpm. The variables discussed earlier in the chapter account for this situation.

The PT is constructed much like the GG turbine. The main differences are (1) the absence of cooling air and (2) the PT blades have interlocking shroud tips for low vibration levels. Honeycomb shrouds in the turbine case mate with the blade shrouds to provide a gas seal. They also protect the case from the high-temperature gas. Two popular methods of blade retention are the bulb type and the dovetail. These methods were discussed earlier in this chapter.

SUMMARY

In this chapter you have learned about principles and construction of GTEs. We have discussed the evolution of the gas turbine, the theory of operation, and the classifications of the different types of engines. There are many other publications that give a more in-depth explanation of gas turbine construction. This chapter was provided to give you the basis on which to expand your knowledge of naval gas turbine engines. You may not feel you understand the temperature-pressure relationships in a simple gas turbine at this point. If so, reread the parts of this chapter related to theory before continuing on to the material that follows.

REFERENCE

Introduction to Marine Gas Turbines, NAVEDTRA 10094. Naval Education and Training Program Development Center, Pensacola, Fla., 1978.

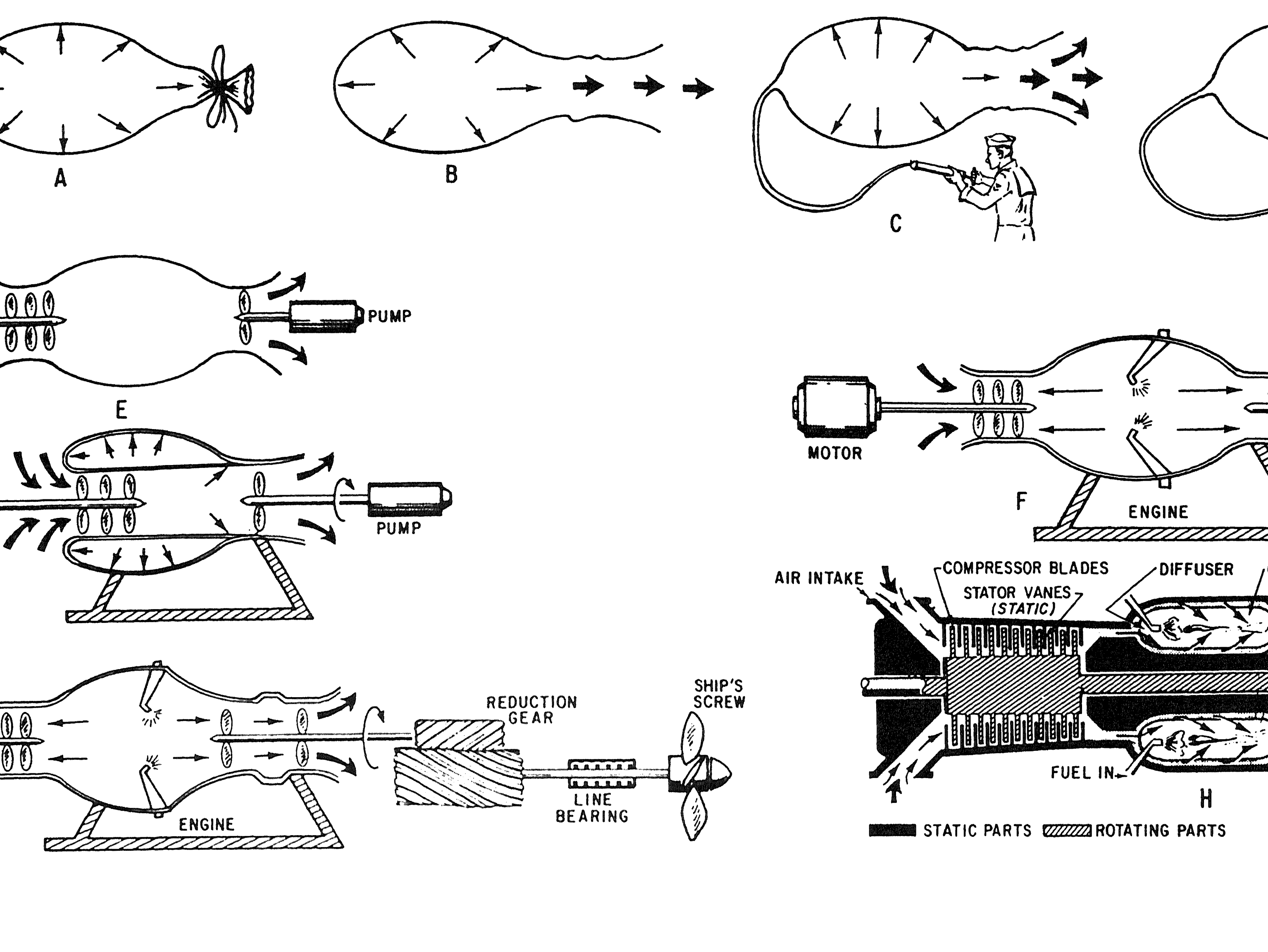

Figure 4-10.—Practical demonstration of gas turb

CHAPTER 5

LM2500 GAS TURBINE CONSTRUCTION

An important part of a GSE's job is to monitor the performance of the LM2500 gas turbine (GT). GSEs make any necessary adjustments to improve or correct the performance of the LM2500 in the FSEE. In discussing the LM2500, we will break down the engine into components and systems. The components we will discuss are the FOD screen and bellmouth, the compressor, combustor, high-pressure (HP) and power turbines, and the accessory gearbox. The systems covered include the fuel oil, lube oil, air intake exhaust, module cooling, and starting systems. We will also cover the base enclosure.

After reading this chapter, you should be very familiar with the construction of the LM2500 GT. You should be able to describe the engine components and their functions. Also, you should be able to discuss the engine systems and how they perform to achieve engine operations.

LM2500 ENGINE COMPONENTS

The LM2500 (figure 5-1) is an axial flow, split shaft gas turbine with an annular-type combustion chamber. The GG components consist of an FOD screen, a bellmouth, and a 16-stage variable geometry compressor. The GG components also include an annular-type combustion chamber and a two-stage HP turbine. The accessory gearbox is mounted on the GG. The PT is aerodynamically linked to the GG and is a six-stage LP turbine. This section will describe each of these components and its function in the engine.

FOD SCREEN

The FOD screen, or air inlet screen (figure 5-2), is mounted on the module barrier wall. The purpose of this screen is to prevent foreign objects larger than 1/4 inch from entering the engine. Normally, the demister pads located in the high hat prevent particles much smaller than this from entering the air intake. The main purpose of the FOD screens is to catch anything that was inadvertently left in the inlet duct. This could include metal particles, tools, or cleaning equipment; although all these items should be removed before engine start. The screen will also prevent items from entering the engine should the blow-in doors open.

After major work, major intake cleaning, or anytime the ship is coming out of a shipyard environment, a special screen is used. It is a nylon screen that attaches over the metal FOD screen.

The nylon screen will catch particles much smaller than the metal screen. You must be careful not to exceed specified throttle limitations when using the nylon screen. Exceeding throttle limitations could starve the engine for air and cause a compressor stall. NAVSEA issues specific instructions for use of the nylon FOD screen.

BELLMOUTH AND BULLETNOSE

The bellmouth and bulletnose (centerbody) (figure 5-2) are mounted on the forward end of the compressor front frame. These components are used to direct air from the inlet plenum to the compressor. The surfaces of the two components are coated to make them smooth to reduce the turbulence of the airflow into the engine. The bellmouth also contains the water wash manifold. The water wash manifold is used to inject fresh water and/or a cleaning solution into the engine. This is done when the engine is being motored.

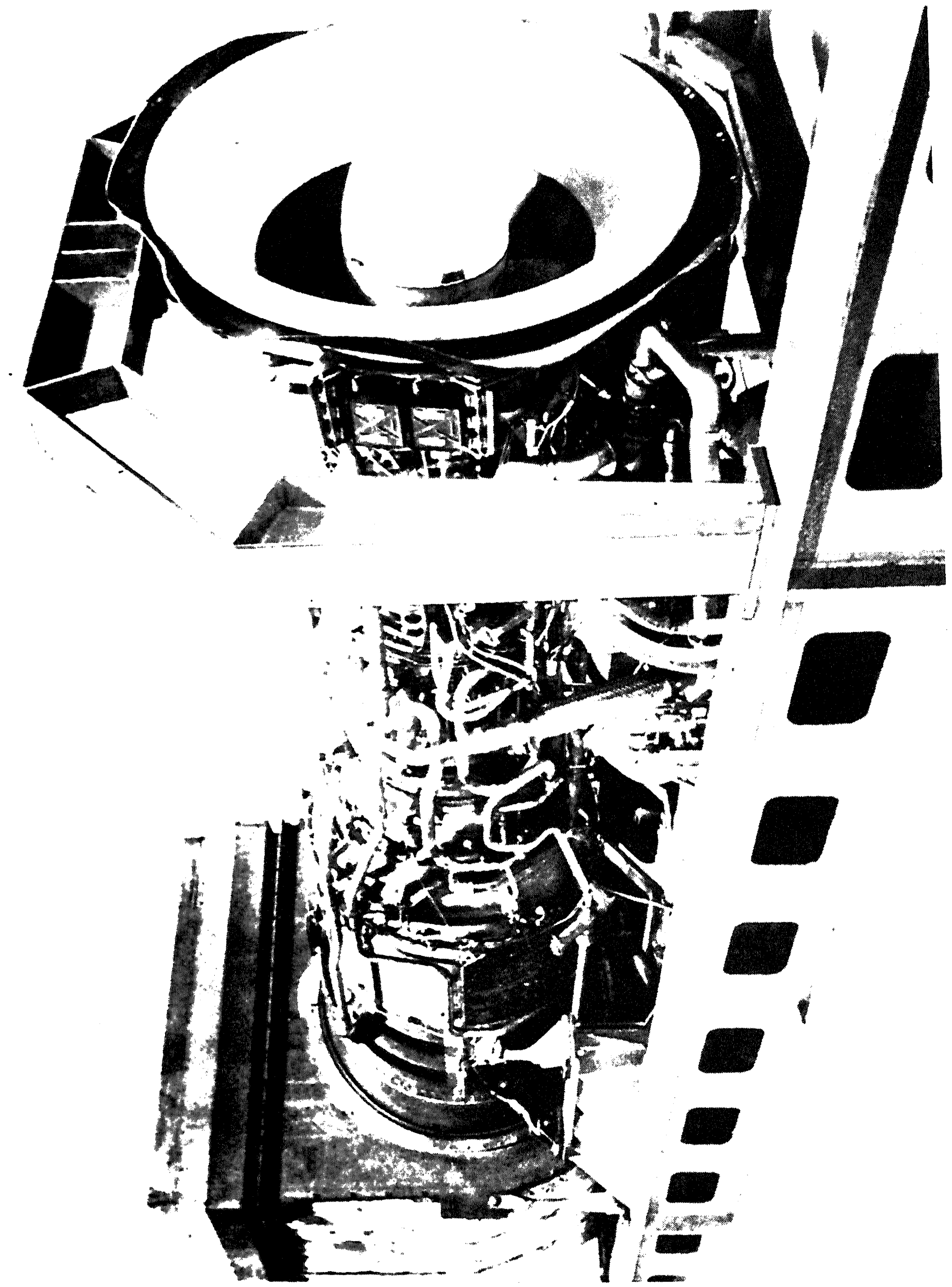

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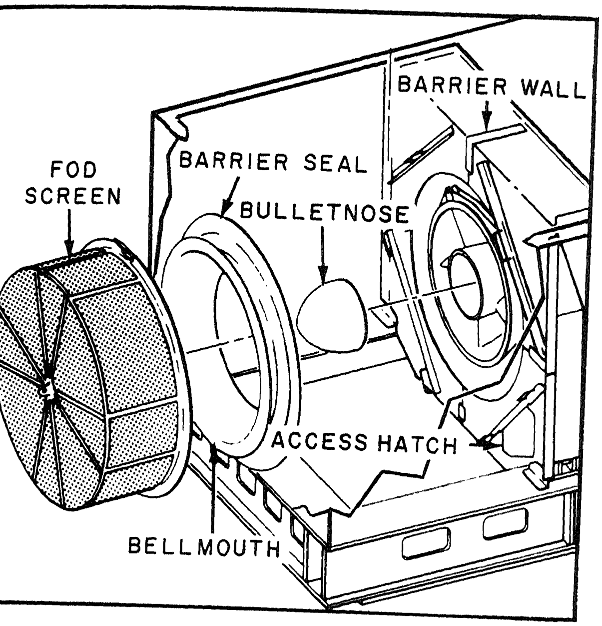
Figure 5-1.—LM2500 gas turbine engine.



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ure 5-2.—LM2500 inlet (FOD screen, bulletnose, and bellmouth).

This procedure is for maintenance purposes to clean deposits from the compressor. The water wash manifold is supplied by a common water wash system piped as a ship's system. We will discuss water wash procedures in chapter 6.

COMPRESSOR

The LM2500 compressor (figure 5-3) is a 16-stage, HP ratio, axial flow design. Major components are the compressor front frame, compressor stator, compressor rotor, and compressor rear frame. The primary purpose of the compressor section is to compress air for combustion; however, some of the air is extracted for engine cooling, sump seal pressurization, and bleed air for ship's service use. Air is drawn in through the front frame. Then it passes through successive stages of compressor rotor blades and compressor stator vanes. The air is compressed as it passes

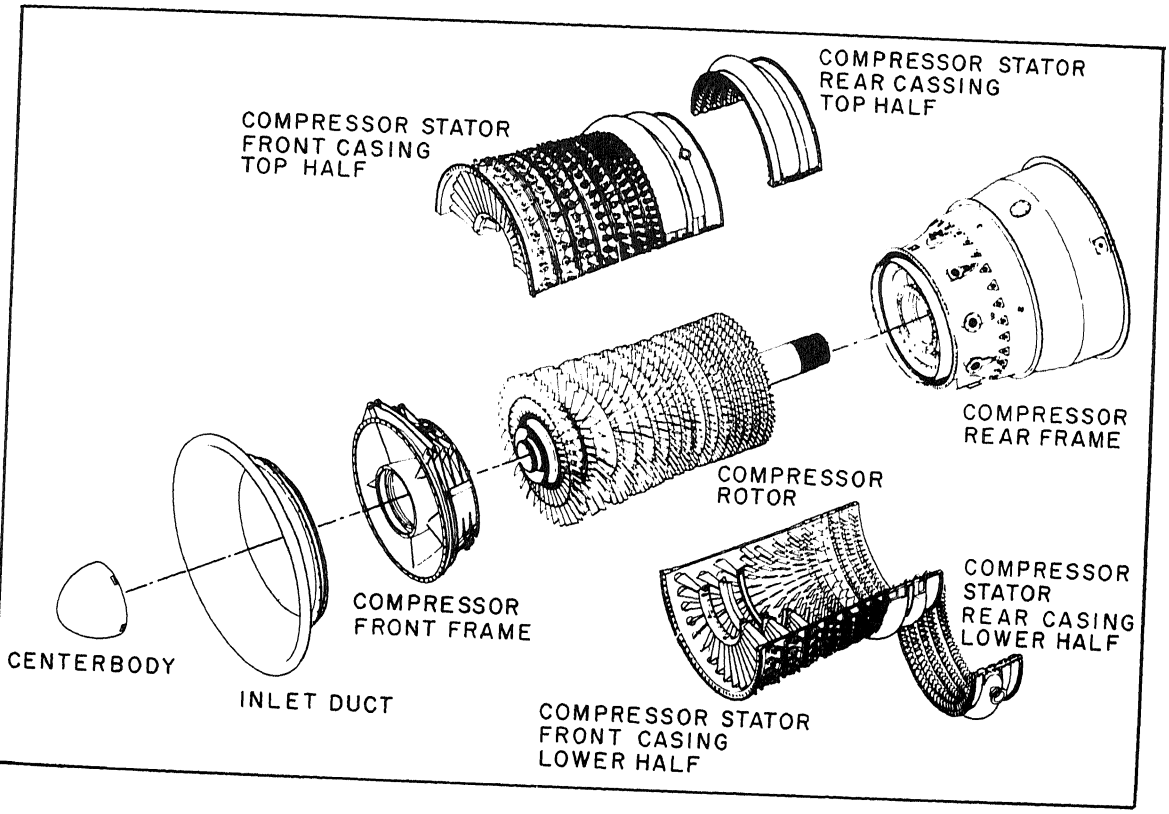

Figure 5-3.—LM2500 compressor components. 293.35

from stage to stage. After passing through 16 stages, the air has been compressed in the ratio of about 16 to 1. The IGVs and first six stages of stator vanes are variable; their angular position is varied as a function of GG speed and CIT by hydraulic fuel pressure from the main fuel control. This provides stall-free operation of the compressor throughout a wide range of speed and inlet temperature. Because these blades are able to be set at different angles, the term variable geometry applies to this compressor.

Compressor Front Frame

The compressor front frame (figure 5-4) provides the forward attachment point for the gas turbine. It supports the forward end of the compressor section and forms a flow path for compressor inlet air. Five struts between the hub

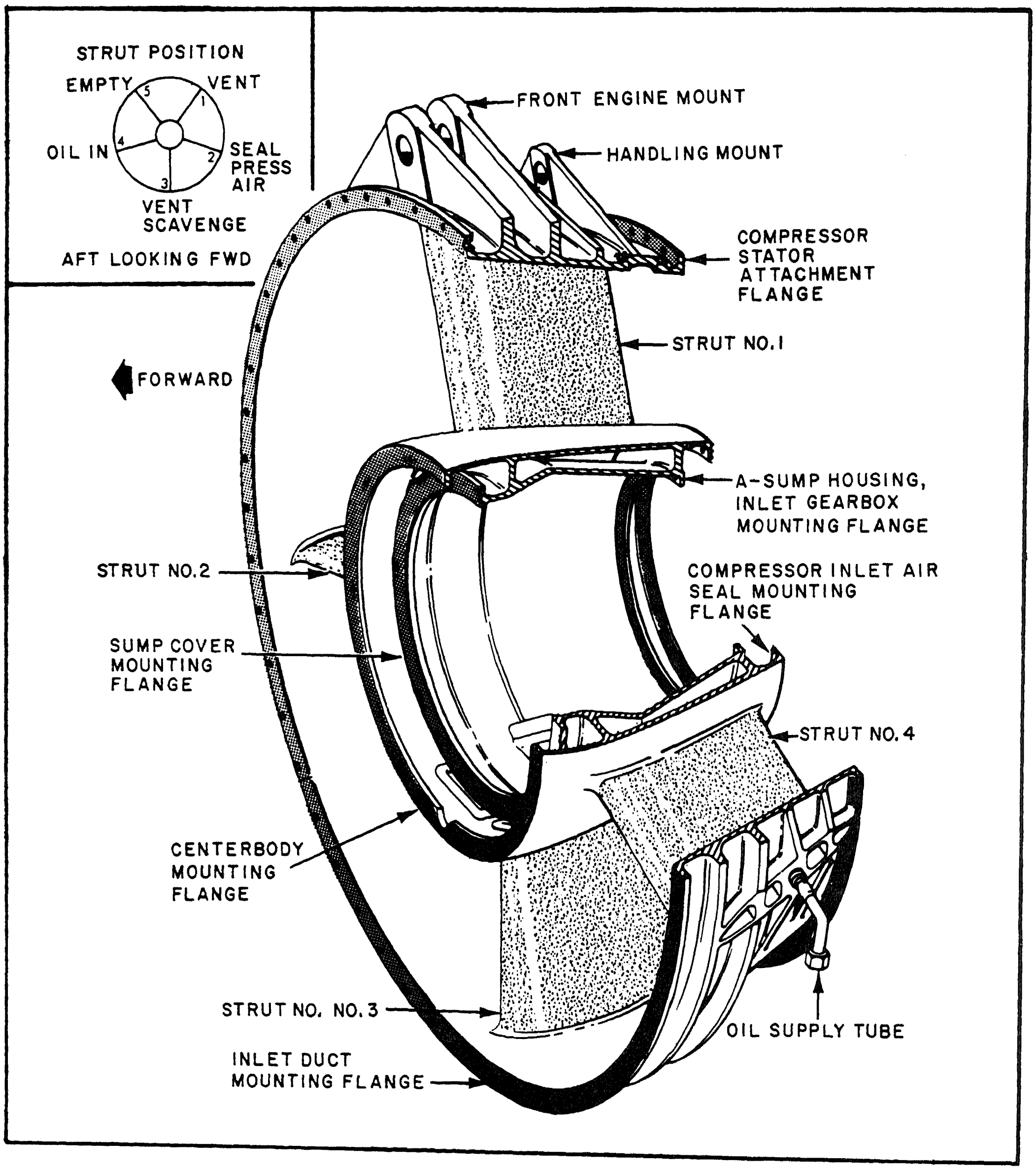

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Figure 5-4.—Propulsion gas turbine module LM2500.

and the outer case provide passages for lubrication oil, scavenge oil, and seal pressurization air. They also vent the A sump components. The No. 3 bearing supports the forward end of the compressor rotor. It and the inlet gearbox are located in the A sump. The compressor inlet total pressure (P_{t2}) probe and CIT sensor are mounted in the outer case. The No. 3 strut (6 o'clock circumferential location) houses the radial drive shaft. The radial drive shaft transfers power from the inlet gearbox to the transfer gearbox mounted on the bottom of the frame.

Compressor Stator

The compressor stator (figure 5-5) has 1 stage of IGVs and 16 stages of stator vanes. The IGVs and stages one through six are variable. The stator case consists of four sections bolted together. These sections are the upper and lower front half and the upper and lower rear half. Three bleed manifolds are welded to the stator casings. The air used for sump seal pressurization and cooling is eighth-stage air. It is extracted from inside the annulus area at the tips of the hollow

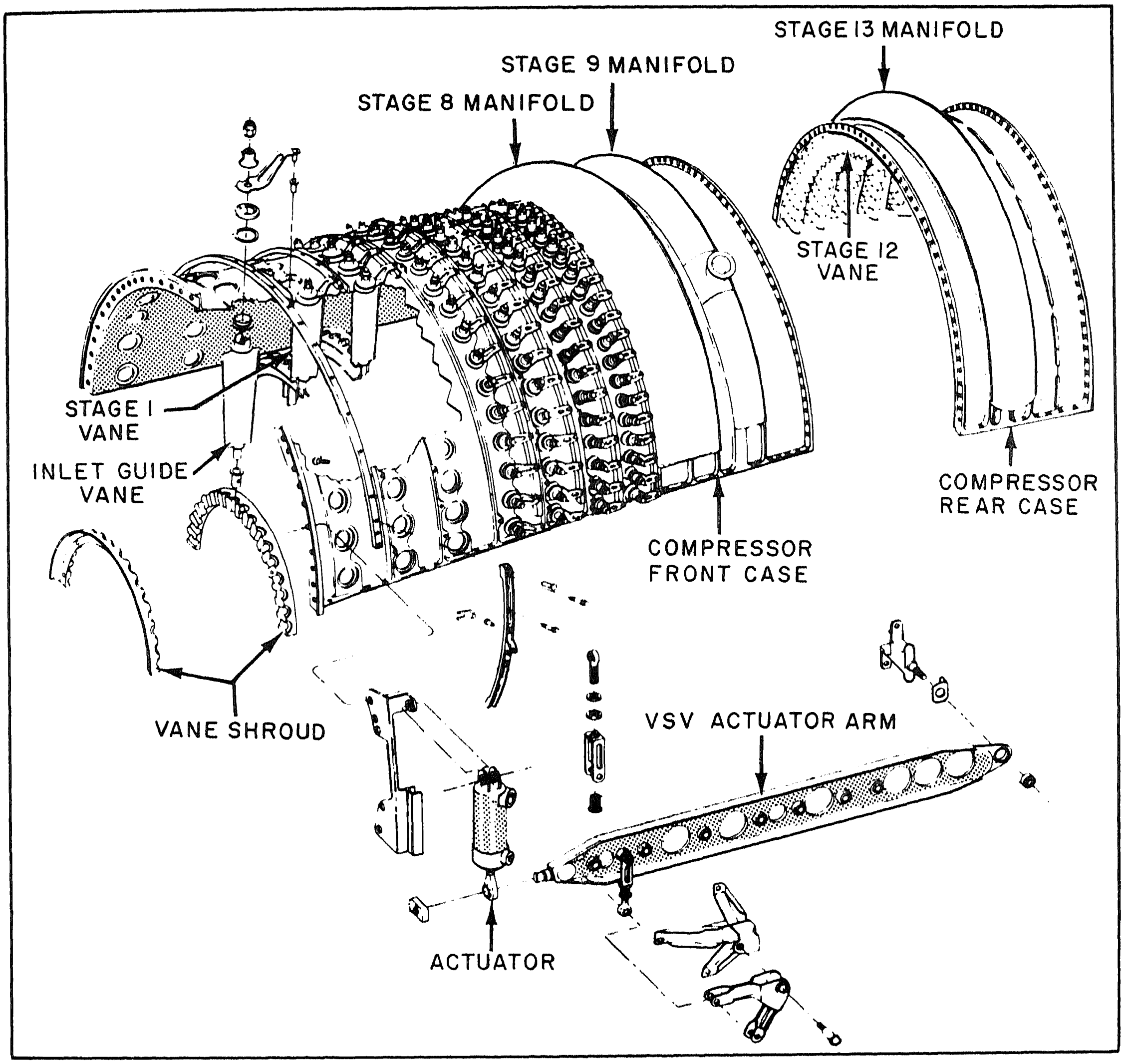

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Figure 5-5.—Compressor stator.

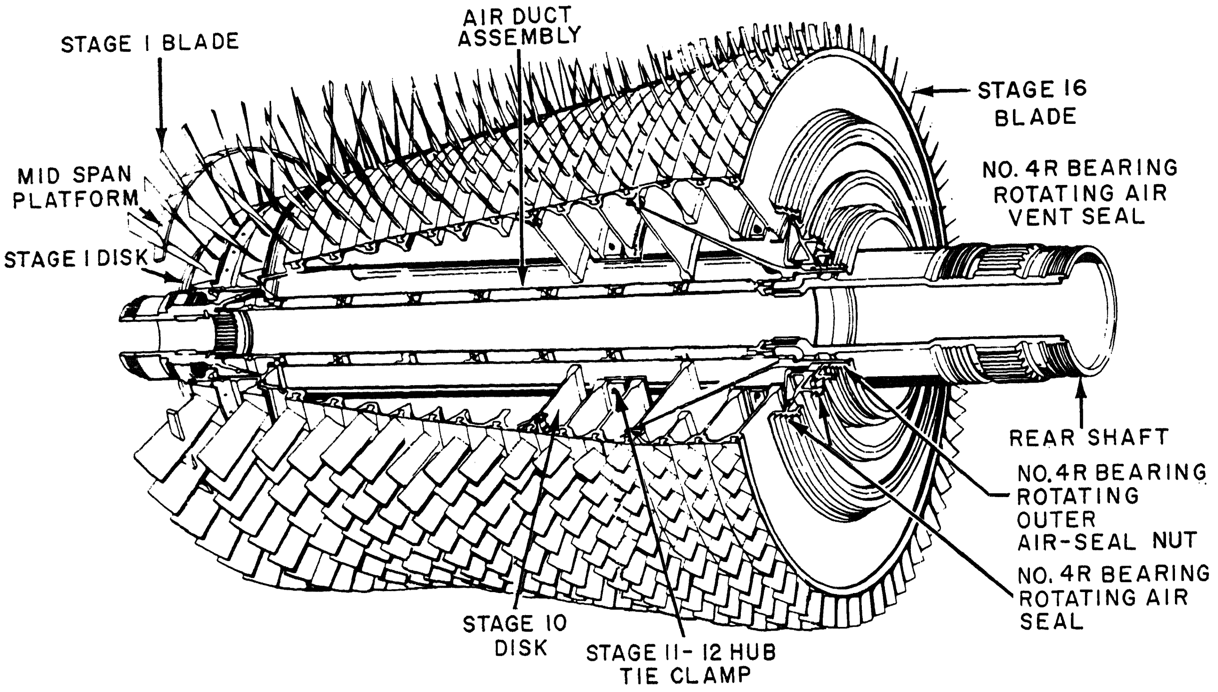

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Figure 5-6.—Compressor rotor.

eighth-stage vanes. Ninth-stage air is used for PT cooling, PT forward seal pressurization, and PT balance piston cavity pressurization. It is extracted from between the ninth-stage vanes through holes in the vane bases. Thirteenth-stage air is used for cooling the second-stage HP turbine nozzle. It is extracted from between the 13th-stage vanes through holes in the vane bases.

The variable vanes are actuated by a pair of master levers. The aft ends of the master levers are attached to pivot posts at about the 10th stage. One is on each side of the casing. Each of the master lever forward ends is positioned by a hydraulic actuator. Adjustable linkages connect directly from the master levers to actuating rings. Lever arms connect the actuating rings to the variable vanes. The variable vanes are positioned by fuel pressure from the main fuel control (MFC).

Compressor Rotor

The compressor (figure 5-6) is a spool/disk structure. Use of spools allows several stages of blades to be carried on a single piece of rotor

Table 5-1.—Compressor Blading

Stage	Number of Blades
Compressor	
1	36
2	26
3	42
4	45
5	48
6	54
7	56
8	64
9	66
10	66
11	76
12	76
13	76
14	76
15	76
16	76
High Pressure Turbine	
1	108 (54 pairs)
2	116 (58 pairs)

structure. An air duct routes eighth-stage air aft from the front frame hub area through the center of the rotor. The routing of air is for pressurization of the B sump seals. The air duct is supported by the front and rear shafts. The first-stage blades have mid span platforms to reduce blade tip vibration. Table 5-1 is a list of the number of blades in each compressor stage.

Compressor Rear Frame

The compressor rear frame consists of the outer case and the hub containing the B sump. It also has ten struts attaching the hub to the outer case. The outer case supports the combustor, the fuel manifold, 30 fuel nozzles, and two spark igniters. It also supports the first-stage HP turbine nozzle support. An internal manifold within the frame extracts air upstream of the combustion area. It routes this 16th-stage air through struts 3, 4, 8, and 9. This provides the ship's bleed air system with compressor discharge air. Six borescope ports are located in the case just forward of the mid flange. They permit inspection of the combustor, fuel nozzles, and the first-stage turbine nozzle.

Two borescope ports are provided in the aft portion of the case for inspection of the turbine blades and nozzles. The B sump contains the No. 4R and 4B bearings (R or no letter = roller, B = ball). The 4B bearing is the thrust bearing for the HP rotor system. The frame struts provide passage for lube oil, scavenge oil, sump vent, and seal leakage. Seal leakage is air leakage past the compressor discharge pressure seals. The frame struts also provide passage for bleed air for masker, prairie, anti-icing, and engine starting services. The rear frame supports the aft end of the compressor stator by the frame's forward flange. It supports the aft end of the compressor rotor by the No. 4R and 4B bearings.

LM2500 COMBUSTOR

The LM2500 combustor (figure 5-7) is an annular type and consists of four major

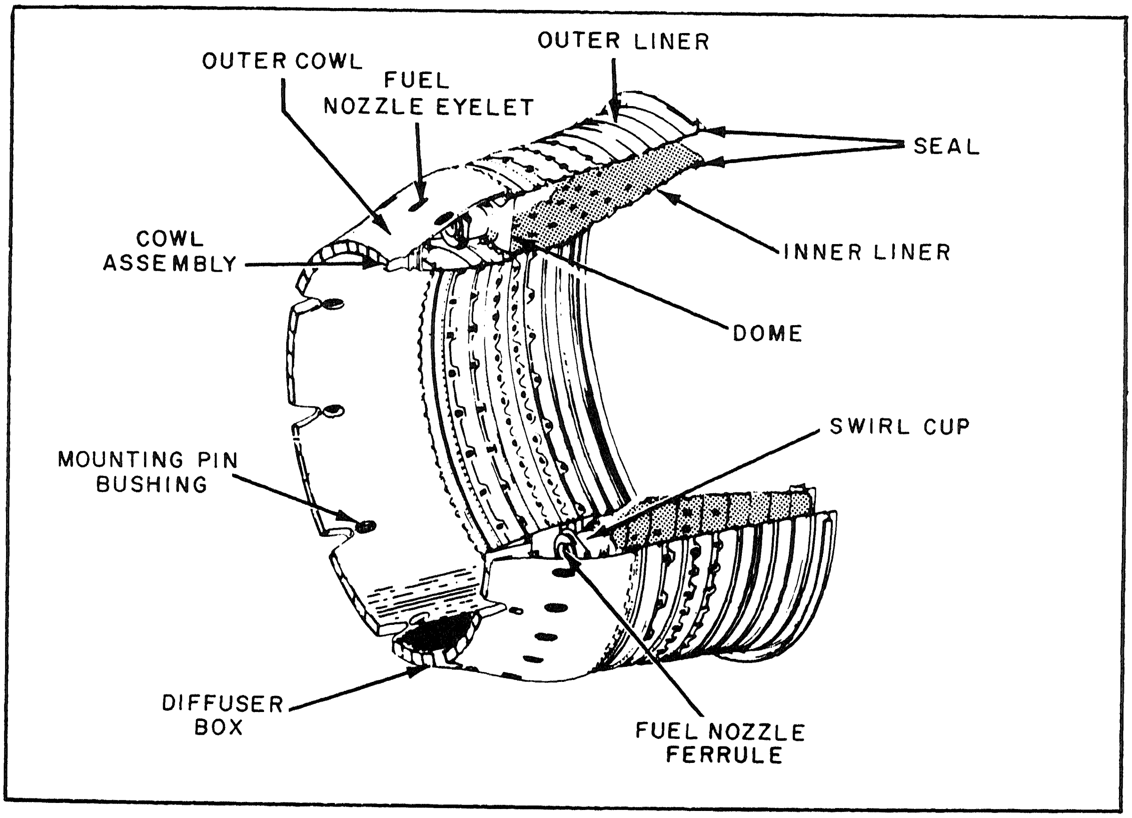

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Figure 5-7.—LM2500 combustor.

components riveted together—cowl (diffuser) assembly, dome, inner liner, and outer liner.

The cowl assembly and the compressor rear frame serve as a diffuser and distributor for the compressor discharge air. They furnish uniform airflow to the combustor throughout a large operating range. This provides uniform combustion and even-temperature distribution at the turbine. The cowl assembly consists of machined ring inner and outer cowl inlets welded to the inner and outer cowl walls. Strength and stability of the cowl ring section are provided with a truss structure. The structure consists of 40 box sections welded to the cowl walls. The box sections also serve as aerodynamic diffuser elements. The cowl assembly leading edge fits within and around the compressor rear frame struts. This arrangement provides a short overall combustor system length.

The combustor is mounted in the compressor rear frame. It is normally on ten equally spaced mounting pins in the forward (low-temperature) section of the cowl assembly. These pins provide positive axial and radial location. They assure centering of the cowl assembly in the diffuser passage. The mounting hardware is enclosed within the compressor rear frame struts so it will not affect airflow.

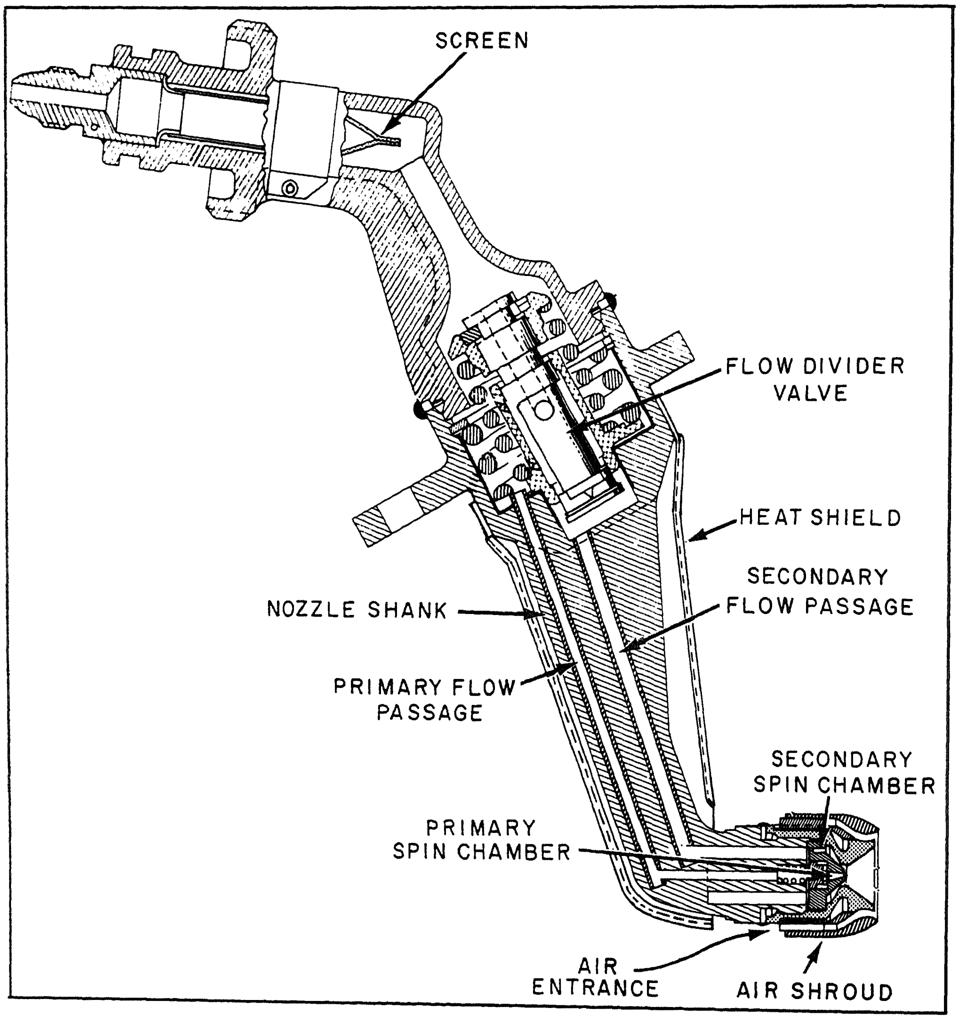

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Figure 5-8.—Fuel nozzle.

Thirty vortex-inducing axial swirl cups in the dome (one at each fuel nozzle tip) provide flame stabilization. They also mix the fuel and air. The interior surface of the dome is protected from the high temperature of combustion by a cooling air film. Accumulation of carbon on the fuel nozzle tips is prevented by venturi-shaped spools attached to the swirler.

The combustor liners are a series of overlapping rings joined by resistance-welded and brazed joints. They are protected from the high combustion heat by circumferential film cooling. Primary combustion and cooling air enters through closely spaced holes in each ring. These holes help to center the flame and admit the balance of the combustion air. Dilution holes on the outer and inner liners provide additional mixing to lower the gas temperature at the turbine inlet. Combustor/turbine nozzle air seals at the aft end of the liners prevent excessive air leakage. The seals also provide for thermal growth.

Fuel Nozzles

The fuel nozzle (figure 5-8) is a dual orifice, swirl atomizer with an internal flow divider. Fuel enters the nozzle through an individual fuel tube encased in a leak barrier (shroud) tube. The 30 fuel nozzles produce the desired spray pattern throughout the range of fuel flows.

Fuel entering the nozzle flows through a 117-micron screen and then the flow divider. When the nozzle is pressurized, primary fuel flows into a drilled passage and tube assembly in the nozzle shank. Then it goes through the primary fuel spin chamber and into the combustor. When nozzle fuel pressure rises to 330-350 psi, the flow divider opens to introduce secondary flow. Secondary fuel flows from the nozzle fuel chamber, through the flow divider, down the nozzle shank, and into the secondary fuel spin chamber. There it combines with the primary flow as it enters the combustor. A small quantity of air is scooped out of the main airstream by the shroud on the nozzle tip. This cools the nozzle tip and retards the accumulation of carbon deposits on its face.

Ignition System

The LM2500 ignition system provides the initial ignition to start combustion in the engine. There are two spark igniters located in the combustor. These are connected to the ignition exciter by the ignition leads. The ignition system is provided with 115 volt a.c. 60 Hz power from the propulsion electronics. Figure 5-9 shows a block diagram of the LM2500 ignition system.

IGNITION EXCITER.—The ignition exciters are the capacitor discharge type. They are located on the right side of the front frame. They are attached to special mounts that absorb shock and vibration. The exciters operate on 115 volt a.c. 60 Hz input. The power is transformed, rectified,

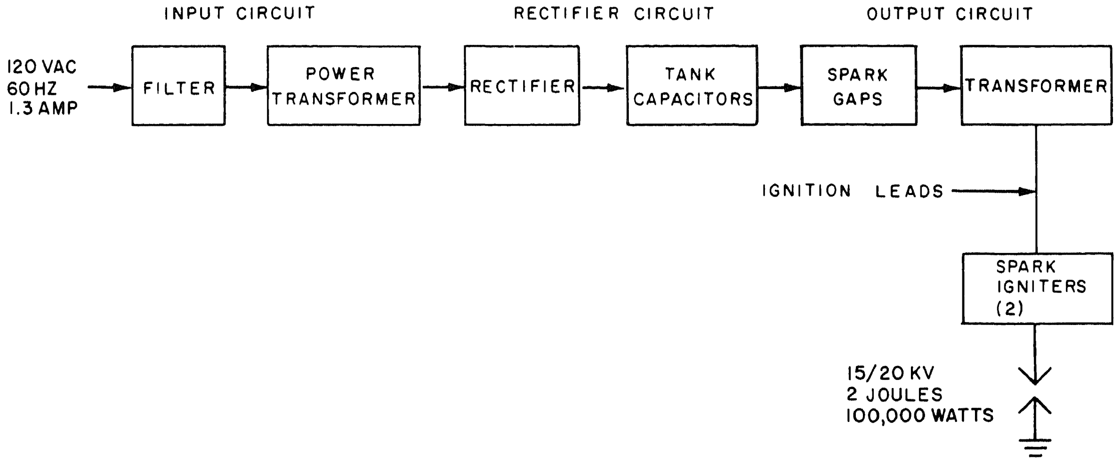

Figure 5-9.—Block diagram of the LM2500 ignition system.

and discharged in the form of capacitor discharge energy pulses. It then flows through the coaxial shielded leads to the spark igniters.

When the starting switch is closed, shipboard 60 Hz power is applied to the exciter circuits. The exciter consists of input, rectifier, discharge, and output circuits. The input circuit includes a filter that prevents feedback of radio-frequency interference (RFI) (generated within the exciter). The filter also prevents introduction of electromagnetic interference (EMI) (generated externally). The input circuit also includes a power transformer that provides step-up voltage for the rectifier circuit. The full-wave rectifier circuit includes diodes that rectify the high voltage a.c. This circuit also includes capacitors that are arranged in a voltage doubler configuration. Tank capacitors store up the d.c. voltage developed in the rectifier circuit. They store this voltage until the potential developed reaches the breakdown point of spark gaps in the discharge circuit. The discharge circuit contains the spark gaps, high-frequency (HF) capacitor, resistors, and HF transformer. When the spark gaps break down, a current (caused by a partial discharge of the tank capacitors) through the HF transformer and in conjunction with the HF capacitor causes a series resonant condition to exist. It also causes HF oscillations to occur in the output circuit. These HF oscillations cause ionization of a recessed spark gap of the igniter plug. A low-resistance path now exists for total discharge of the tank capacitor producing a high energy spark used to ignite the fuel within the combustor. The spark rate is determined by the total rectifier circuit resistance. This controls the resistance-capacitance (RC) time constant in the charging circuit.

SPARK IGNITERS.—The spark igniters (figure 5-10) are the surface gap type. They have internal passages for air cooling and air vents. These passages prevent the accumulation of carbon in interior passages. The igniter has a seating flange with attached copper gaskets for sealing purposes. Grooves in the outer surface of the tip and axial holes cool the outer and inner electrodes with compressor bleed air.

The surface gap will ionize at 8,500 volts when dry and 15,000 volts if wet. There is a discharge of two joules of energy across the gap.

CAUTION

This energy level is lethal. Output from the spark exciter, leads, or igniter should never be contacted by personnel. A grounding probe must be used to ground the ignition system when maintenance is performed.

IGNITION LEADS.—The ignition leads are low-loss connections between the ignition exciters and the spark igniters. They are coaxial, having metallic shielding that incorporates copper inner braid, sealed flexible conduit, and nickel outer braid.

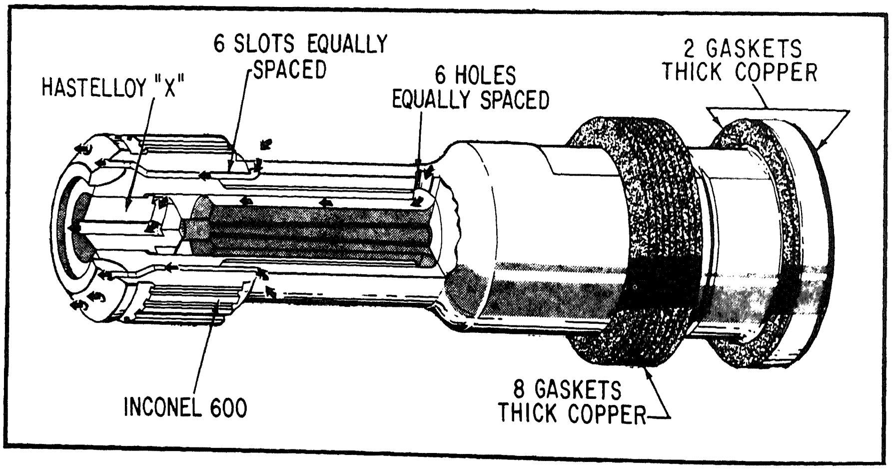

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Figure 5-10.—Spark igniter.

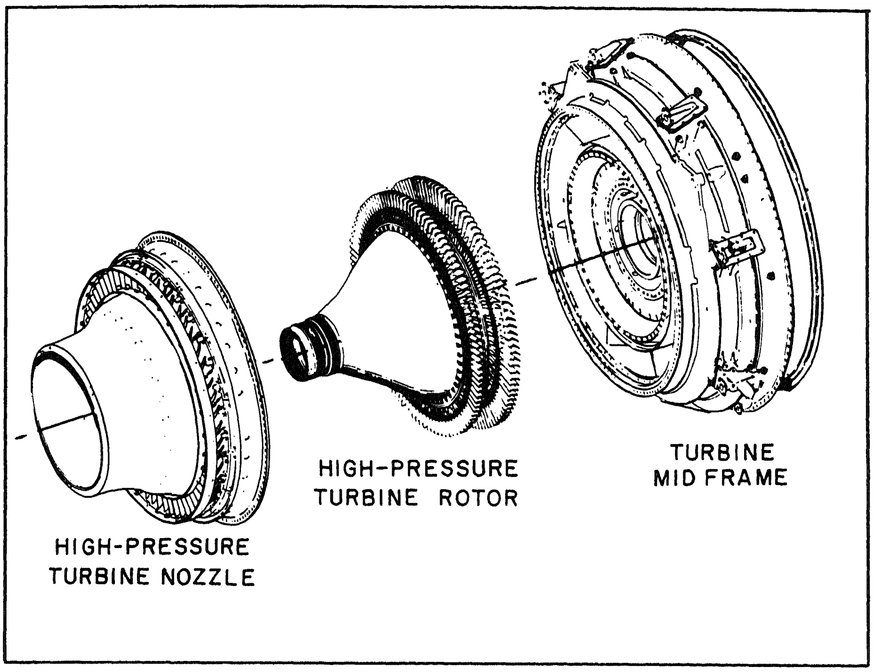

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Figure 5-11.—High-pressure turbine.

HIGH-PRESSURE TURBINE

The HP turbine section (figure 5-11) consists of the HP turbine rotor, first- and second-stage turbine nozzle assemblies, and turbine mid frame. The turbine rotor extracts energy from the gas stream to drive the compressor rotor. The turbine rotor is mechanically coupled with the compressor rotor. The turbine nozzles direct the hot gas from the combustor onto the rotor blades at the best angle and velocity.

The front end of the turbine rotor is supported at the compressor rotor rear shaft by the No. 4 bearings. The rear of the rotor is supported by the No. 5 bearing in the turbine mid frame. The turbine nozzles are contained in and supported by the compressor rear frame. The turbine mid frame, besides supporting the aft end of the turbine rotor, also supports the front end of the PT. It contains the transition duct. The gas flows throughout this duct from the HP turbine section into the PT.

High-Pressure Turbine Rotor

The HP turbine rotor (figure 5-12) has a conical forward shaft and two disks with blades and

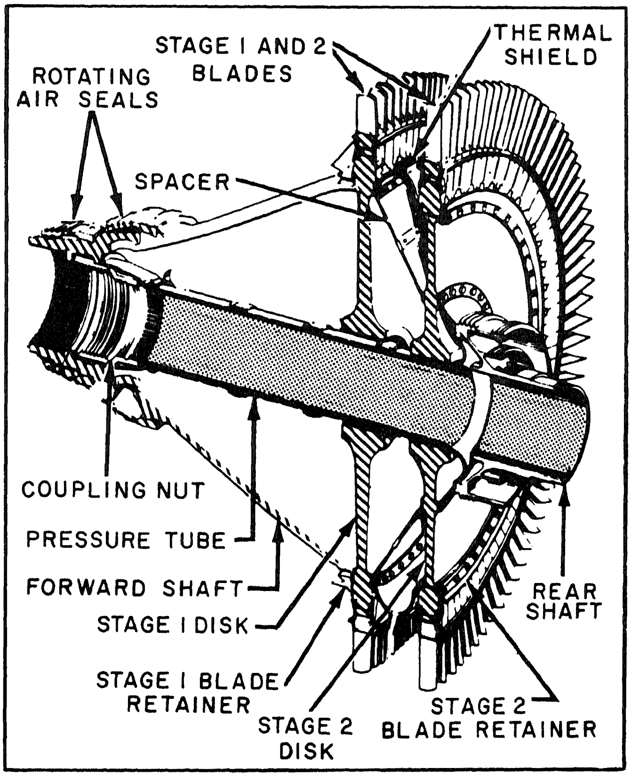

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Figure 5-12.—High-pressure turbine rotor.

retainers. It also has a conical rotor spacer, a thermal shield, and a rear shaft.

The forward turbine shaft transmits energy to the compressor rotor. Two seals are on the forward end of the shaft. The front seal helps prevent compressor discharge pressure (CDP) air from entering the B sump. The other seal maintains CDP in the plenum formed by the rotor and the combustor. This plenum is a balance chamber that provides a corrective force that minimizes the thrust load on the No. 4B bearing.

Turbine blades in both stages are long shanked and internally air cooled. Use of long-shank blades provides thermal isolation of dovetails, cooling air flow paths, high damping action for low vibration, and low disk rim temperature. The blades are brazed together in pairs. The turbine blades are coated to improve erosion and oxidation resistance.

HIGH-PRESSURE TURBINE ROTOR COOLING.—The HP turbine rotor (figure 5-13) is cooled by a continuous flow of compressor discharge air. This air passes through holes in the first-stage nozzle support and forward turbine shaft. The air cools the inside of the rotor and both disks before passing between the paired dovetails and out to the blades.

HIGH-PRESSURE TURBINE BLADE COOLING.—Both stages of HP turbine blades (figure 5-14) are cooled by compressor discharge air. This air flows through the dovetail and through blade shanks into the blades. First-stage blades are cooled by internal convection and external film cooling. The convection cooling of the center area is done through a labyrinth within the blade. The leading edge circuit provides internal convection cooling by airflow through the labyrinth. Then air flows out through the leading edge tip and gill holes. Convection cooling of the trailing edge is provided by air flowing through the trailing edge exit holes. Second-stage blades are cooled by convection, with all the cooling air discharged at the blade tips.

High-Pressure Turbine Nozzles

High-pressure turbine nozzles are installed in two sets, the first stage and the second stage. As there are significant differences between the two stages, we will discuss them separately.

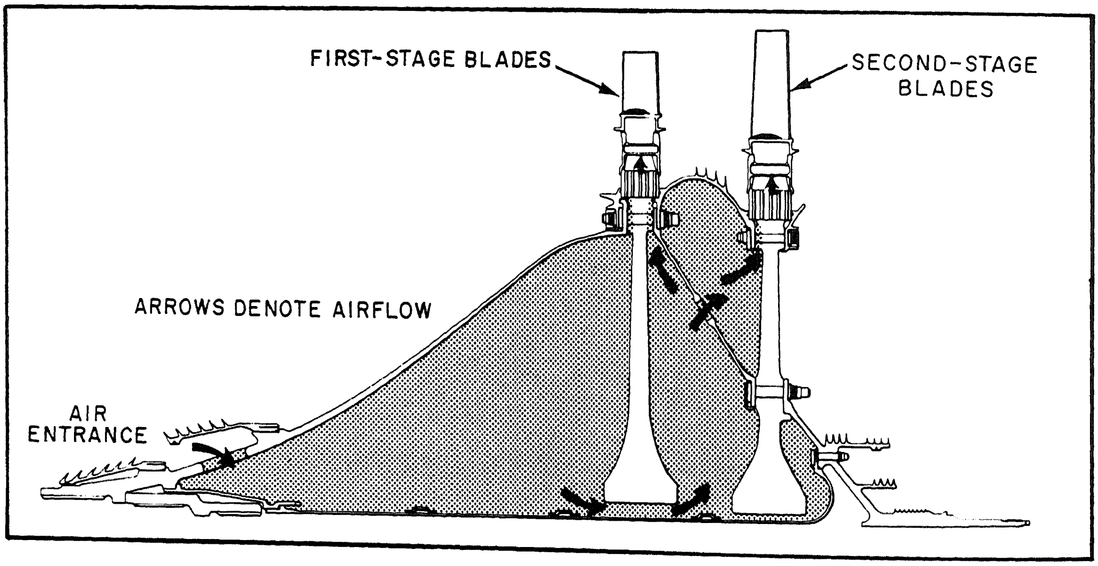

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Figure 5-13.—High-pressure turbine rotor cooling.

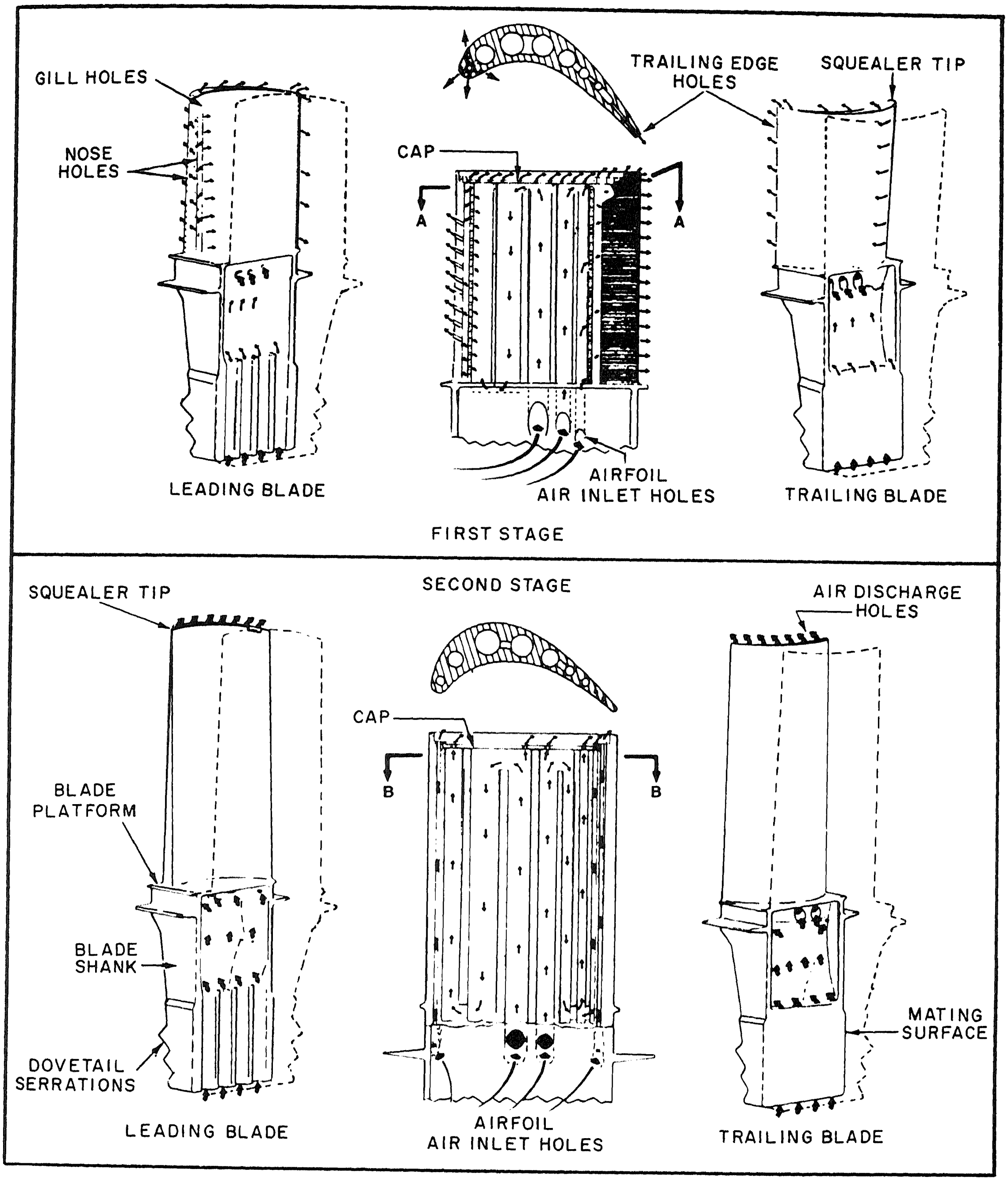

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Figure 5-14.—High-pressure turbine rotor blade cooling.

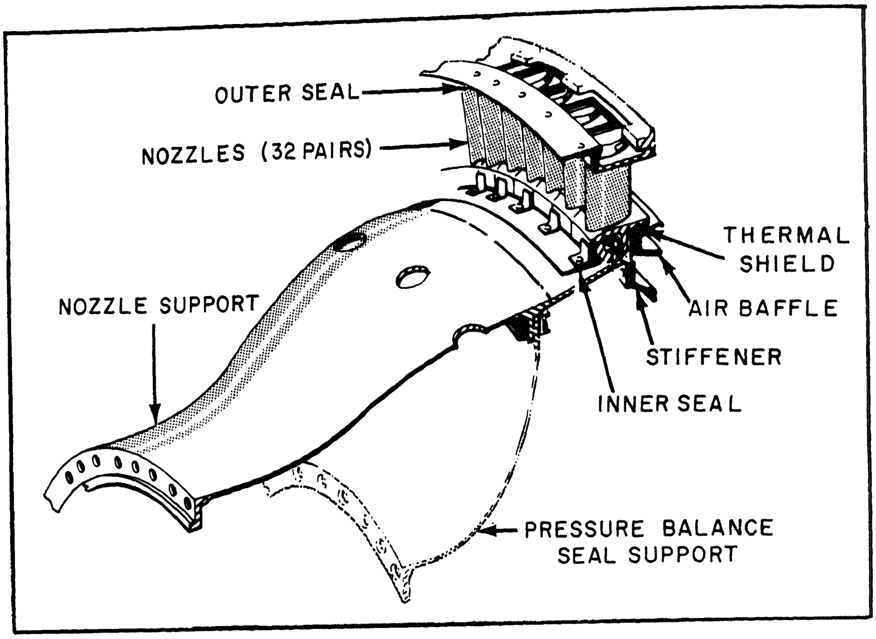

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Figure 5-15.—First-stage high-pressure turbine nozzle.

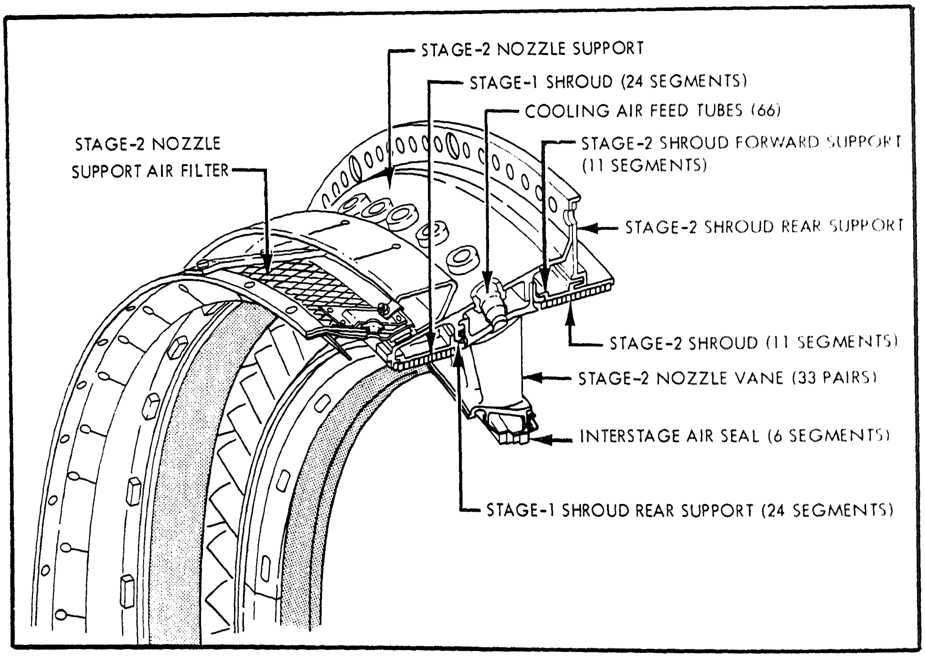

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Figure 5-16.—Second-stage high-pressure turbine nozzle.

FIRST-STAGE TURBINE NOZZLE ASSEMBLY.—The major parts of the first-stage turbine nozzle assembly (figure 5-15) are the nozzle support, nozzles, inner seal, outer seal, and baffles. The nozzles are coated to improve erosion and oxidation resistance. They are bolted to the first-stage nozzle support. They receive axial support from the second-stage nozzle support. There are 32 nozzle segments in the assembly. Each segment consists of two vanes. The vanes are cast and then welded into pairs (segments) to decrease the number of gas leakage paths. The first-stage nozzles are cooled by air from the compressor's 16th stage.

SECOND-STAGE TURBINE NOZZLE ASSEMBLY.—The major parts of the second-stage nozzle assembly (figure 5-16) are the nozzles, nozzle support, stage-1 and stage-2 turbine shrouds, and interstage seal.

The nozzle support is a conical section. It has a flange that is bolted between the flanges of the compressor rear frame and the turbine mid frame. The support mounts the nozzles, cooling air feeder tubes, and the stage-1 and stage-2 turbine shrouds.

The nozzles are cast and then coated. The vanes (two per nozzle) direct the gas stream onto the second-stage turbine blades. The inner ends of the nozzles form a mounting circle for the interstage seal attachment.

The turbine shrouds form a portion of the outer aerodynamic flow path through the turbine. They are located radially in line with the turbine blades. The turbine shrouds form a pressure seal to prevent excessive gas leakage over the blade tips. The sealing (rubbing) surface is nickel-aluminide compound. Stage 1 has 24 segments; stage 2 has 11 segments.

The interstage seal has six segments bolted to the nozzles. It minimizes the gas leakage between the stage-2 nozzle and the turbine rotor. The sealing surface has four steps for maximum effectiveness of each sealing tooth. The seals are pregrooved to preclude seal rub under emergency shutdown conditions. The second-stage nozzles are cooled by 13th-stage bleed air.

Turbine Mid Frame

The turbine mid frame (figure 5-17) supports two areas. It supports the aft end of the HP

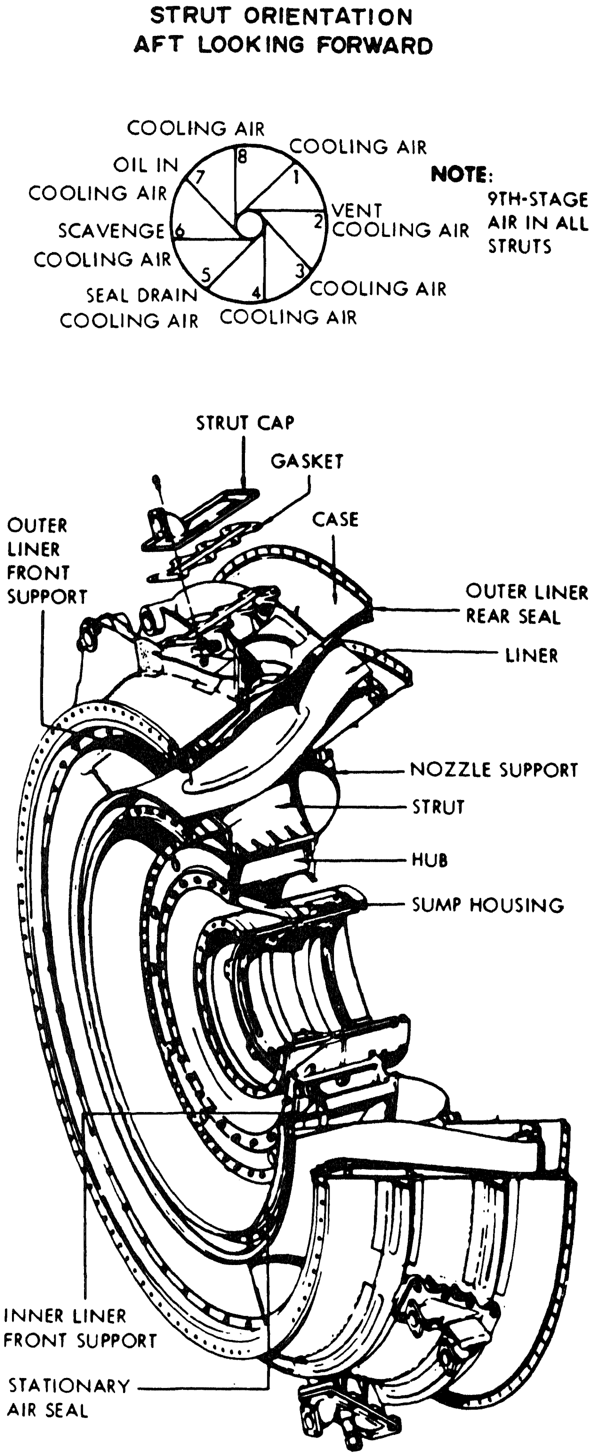

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Figure 5-17.—Turbine mid frame.

turbine rotor and the forward end of the PT rotor. It is bolted between the rear flange of the compressor rear frame and the front flange of the PT stator. The frame provides a smooth diffuser flow passage for HP turbine discharge air into the PT. Piping for bearing lubrication and seal pressurization is located within the frame struts. The frame has ports for the HP turbine exhaust thermocouples and pressure probes. These ports also provide access for borescope inspection of the PT inlet area. The PT first-stage nozzle assembly is part of the frame.

POWER TURBINE

The PT (figure 5-18) is used to extract the remaining energy from the hot gas. This energy is used to power the ship for propulsion. The PT consists of three components: the rotor, the stator, and the turbine rear frame. The PT is a separate unit from the GG. If the GG must be changed out, it is unbolted from the PT and removed separately. To remove the PT, though, you have to also remove the GG.

Power Turbine Rotor

The PT rotor (figure 5-19) consists of six disks, each having integral spacers. Each disk spacer is attached to the adjacent disk by close-fitting bolts. The front shaft is secured between stages-2 and -3 spacers. The rear shaft is secured between stages-5 and -6 spacers.

Blades of all six stages have interlocking tip shrouds for low vibration levels and are retained in the disks by dovetails. Replaceable rotating seals are secured between the disk spacers. They mate with stationary seals to prevent excessive gas leakage between stages.

Power Turbine Stator

The PT stator (figure 5-19) has two casing halves, stages-2 through -6 turbine nozzles, and six stages of blade shrouds. The stage-1 nozzle is part of the turbine mid frame assembly. Stages-2 and -3 nozzles have welded segments of six vanes each. Stages-4, -5, and -6 nozzles have segments of two vanes each.

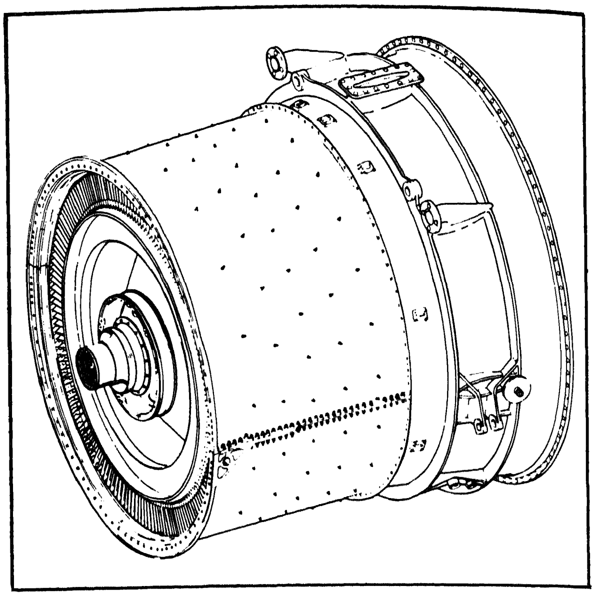

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Figure 5-18.—LM2500 power turbine.

Turbine Rear Frame

The turbine rear frame (figure 5-20) has an outer casing, eight equally spaced radial struts, and a single-piece cast steel hub. It forms the PT exhaust flow path and supports the aft end of the PT. It also supports the forward end of the high-speed flexible-coupling shaft. The turbine rear frame hub supports the inner deflector of the exhaust system. It also has a bearing housing for the No. 7B and No. 7R bearings. The hub and the bearing housings have flanges to which air and oil seals are attached to form the D sump. The frame casing supports the outer cone of the exhaust system and provides attaching points for the gas turbine rear supports. The struts have service lines for lubrication, scavenge, and vent. The PT speed pickups also pass through the struts.

ACCESSORY DRIVE SECTION

The accessory drive section (figure 5-21) has three components. These are the inlet gearbox, a radial drive shaft, and a transfer gearbox. The inlet gearbox is located in the hub of the front frame; the radial drive shaft is inside the front

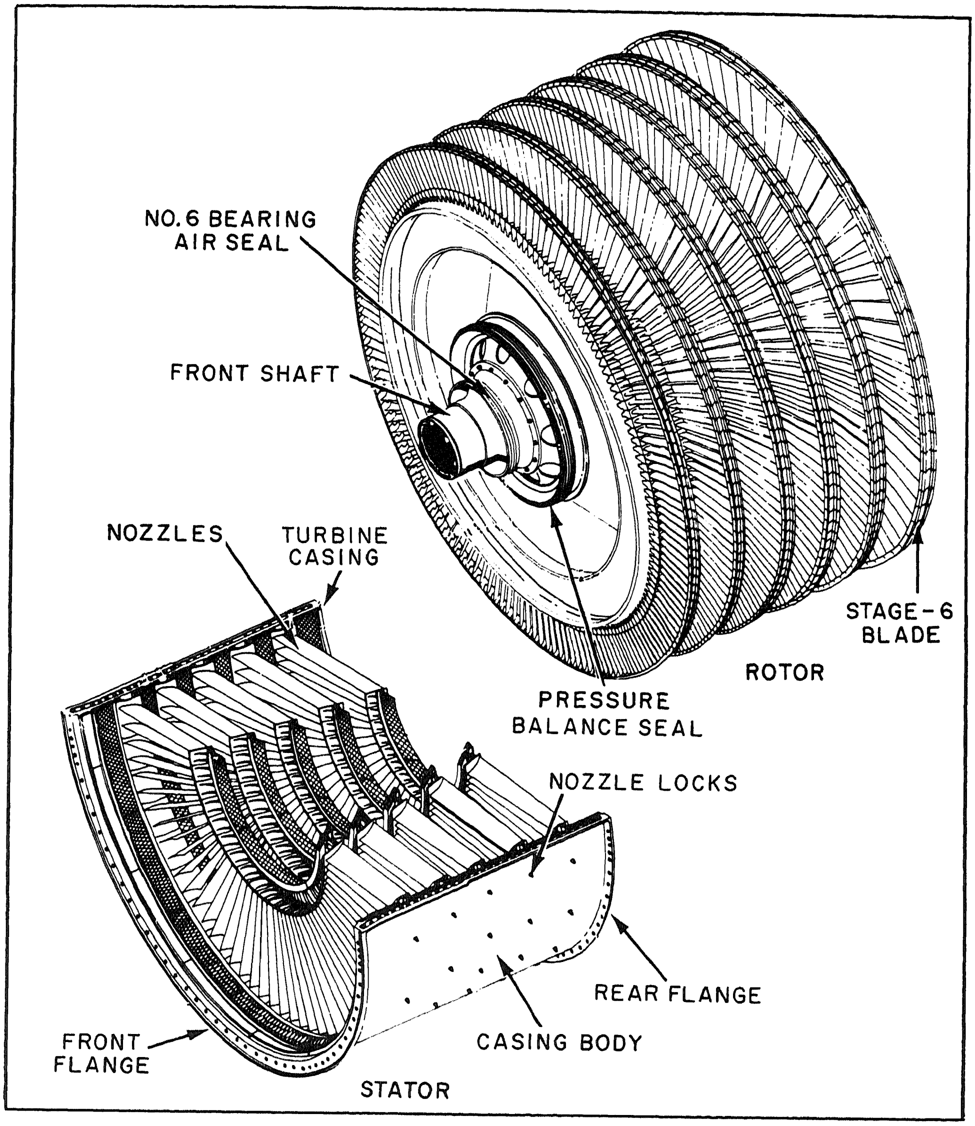

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Figure 5-19.—Power turbine rotor and stator.

frame 6 o'clock strut; the transfer gearbox is bolted underneath the front frame. The accessory drive section provides the drive train for the fuel pump with main fuel control, the lube and scavenge pump, and the pneumatic starter. It also provides mounting for the GG speed pickup. These are all mounted on the aft side of the aft transfer gearbox (accessory gearbox). An air/oil separator mounted on the front is part of the gearbox. Power to drive the accessories is extracted from the compressor rotor through a large-diameter hollow shaft. This is spline-connected to the rotor front shaft. A set of bevel gears in the inlet gearbox transfers this power to the radial drive shaft. This, in turn, transmits the power to another set of bevel gears in the forward section of the transfer gearbox. A short horizontal drive shaft transmits the power to the accessory drive adapters in the aft section of the transfer gearbox.

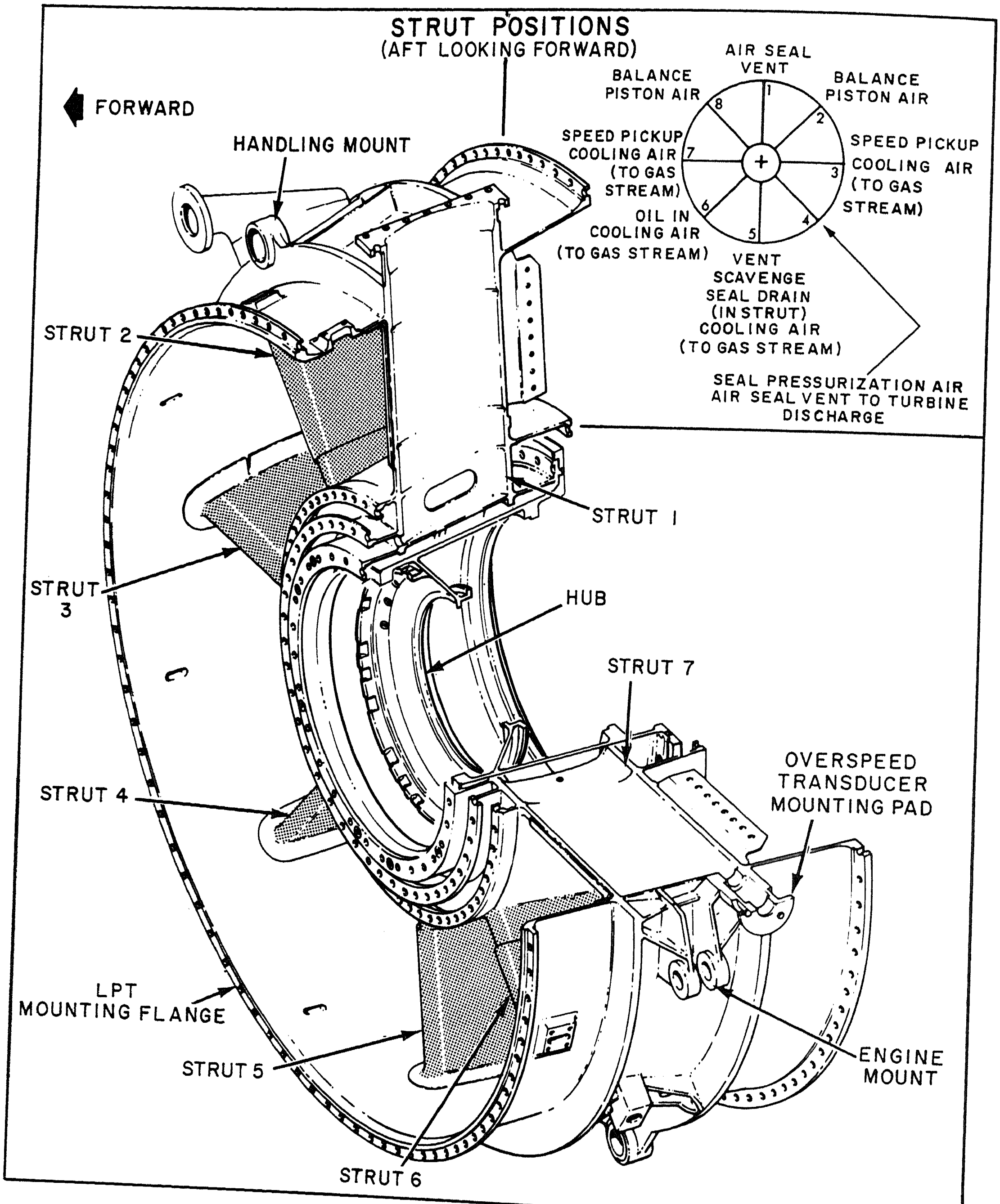

Figure 5-20.—Power turbine rear frame.

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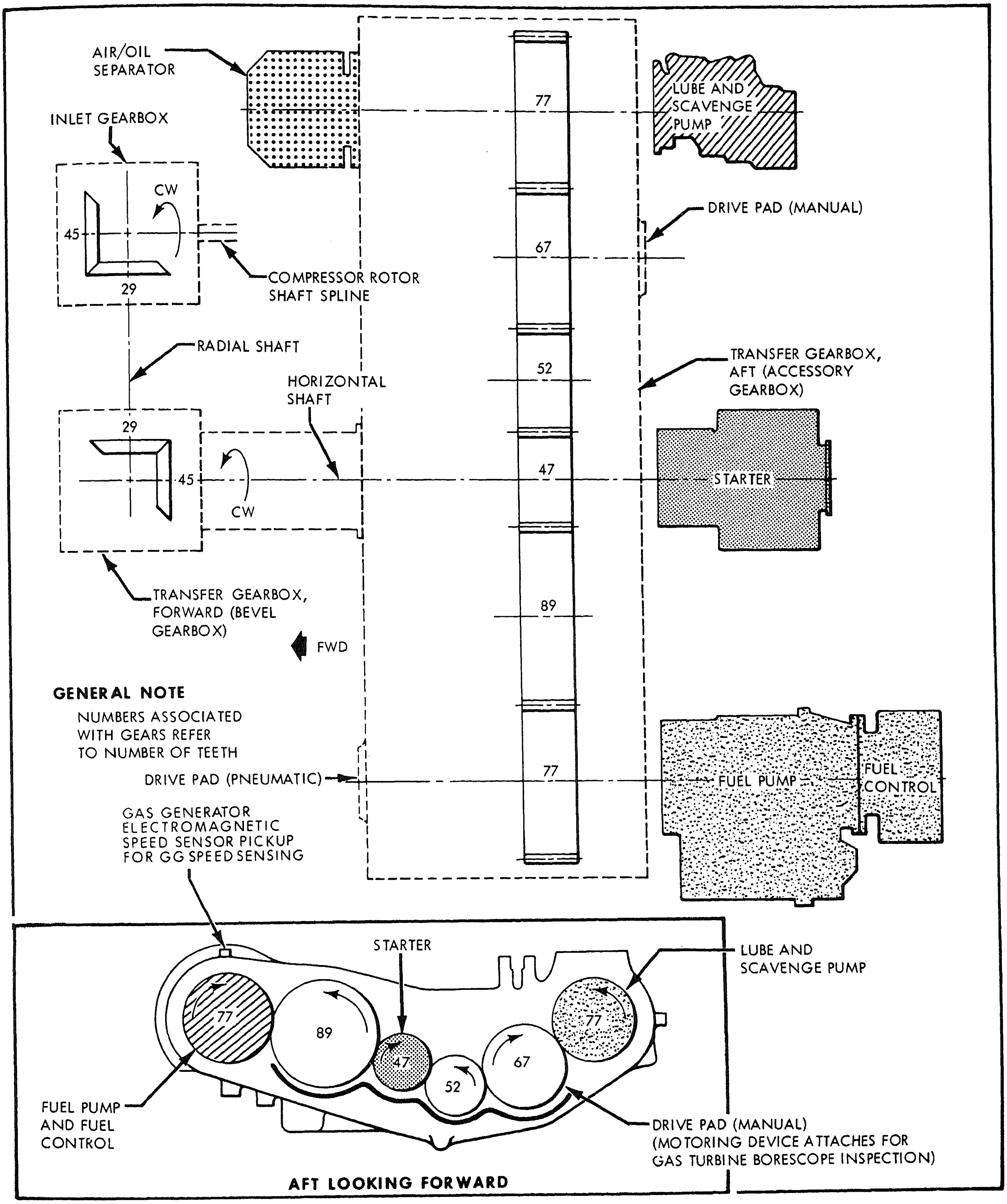

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Figure 5-21.—Accessory drive section.

Inlet Gearbox

The inlet gearbox (figure 5-22) has a cast aluminum casing, a shaft, a pair of bevel gears, bearings, and oil jets. The casing, bolted inside the compressor front frame hub, mounts two duplex ball bearings and a roller bearing. Internal oil passages and jets provide lubrication for the bearings and gears. The shaft rotates on a horizontal axis. It is splined at the aft end to mate with the compressor rotor front shaft. The shaft is supported by a duplex ball bearing. It mounts the upper bevel gear on the forward end. The lower bevel gear rotates on a vertical axis. It is supported at its upper end by a roller bearing. It is supported at its lower end by a duplex ball bearing. The lower end is splined to mate with the radial drive shaft.

Radial Drive Shaft

The radial drive shaft is a hollow shaft externally splined at each end. It mates with bevel gears in the inlet and transfer gearboxes.

Transfer Gearbox

The transfer gearbox assembly (figure 5-23) has a two-piece aluminum casing, an air/oil separator, gears, bearings, seals, oil nozzles, and accessory adapters. The forward section contains a set of right-angle bevel gears and a horizontal drive shaft. The drive shaft transmits power to the gear train in the aft section. The accessories are the fuel pump, main fuel control, lube and scavenge pump, air/oil separator, and starter. They are mounted on the aft section. For this reason, the aft section of the transfer gearbox is also called the accessory gearbox. These accessories will be described later in this chapter when we discuss the engine systems. The plug-in gear concept is used on all accessory adapters and idler gears in the aft section. This permits replacement of entire gear, bearing, seal, and adapter assemblies without disassembling the gearbox. Lubrication of the gears and bearings is provided by internal tubes and jets. The transfer gearbox is assembled as a single unit and is bolted to the engine externally. Thus, you can replace the

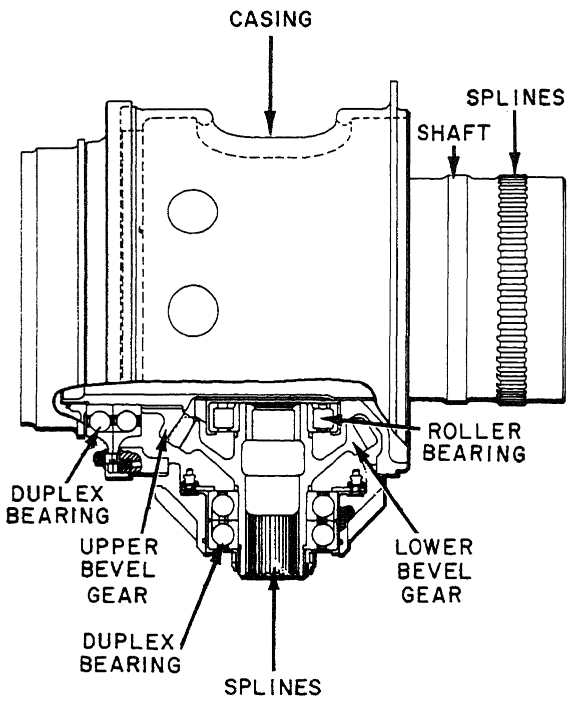

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Figure 5-22.—Inlet gearbox.

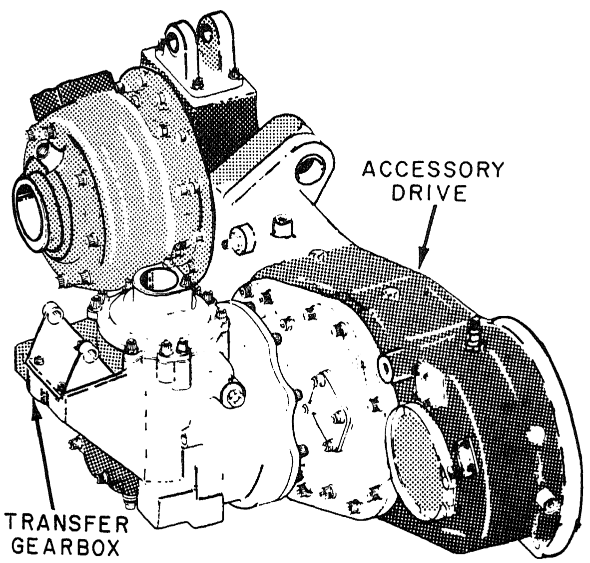

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Figure 5-23.—Transfer gearbox and accessory drive.

entire unit without removing the engine from the enclosure.

LM2500 FUEL SYSTEM

The fuel and speed covering system of the LM2500 regulates and distributes fuel to the combustor section of the engine. This fuel is used to control the speed of the GG. The PT speed is not directly controlled by the fuel. It is controlled by the amount of energy in the hot gas that is extracted by the PT. The fuel used by the LM2500 is supplied by the engine room fuel system. You can find more information on your ship's fuel system in the Engineering Operational Sequence System (EOSS).

The fuel system of the LM2500 has several components. These components are the fuel pump, main fuel control, a pressurizing valve, two fuel shutdown valves, and 30 fuel nozzles. Also included are the CIT sensor, the VSV actuator, the fuel manifold pressure transducer, the purge valve, and the fuel manifold and shroud. We will discuss each of these components individually and explain how they relate to the system. Refer to figure 5-24 which shows the flow path of the fuel to each of these components.

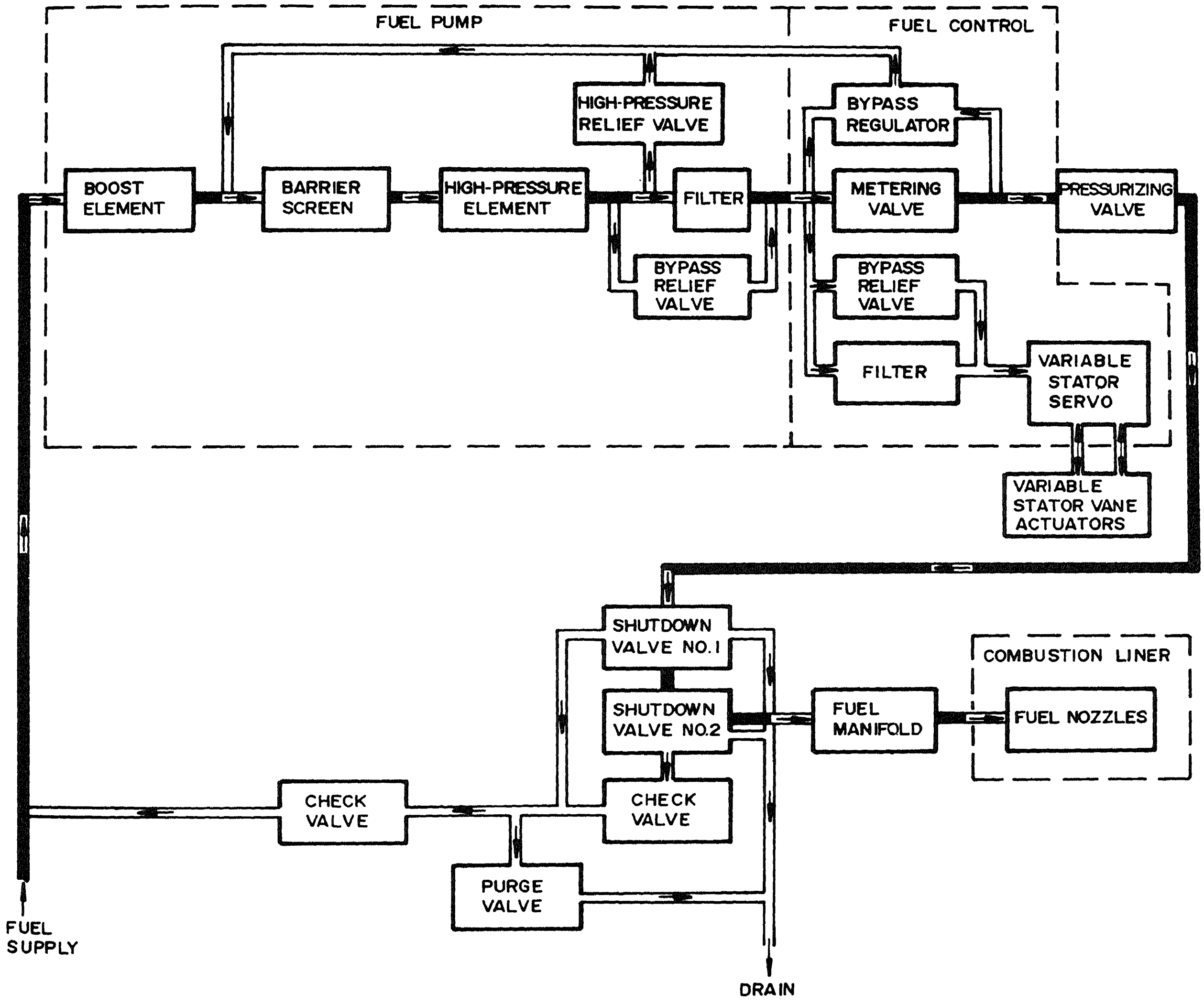

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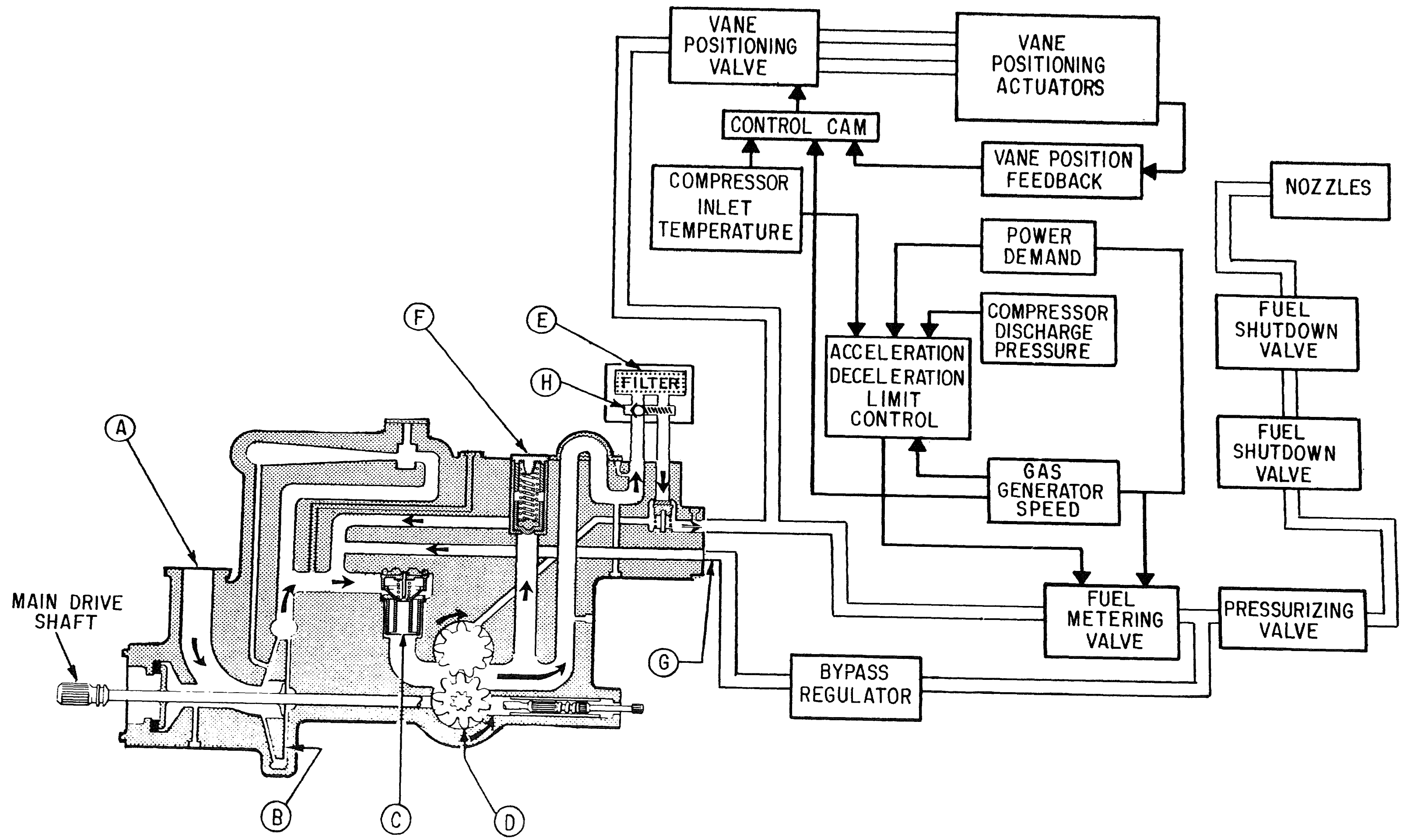
Figure 5-24.—LM2500 fuel system block diagram.



A. FUEL INLET
B. CENTRIFUGAL PUMPING ELEMENT
C. STRAINER ELEMENT
D. HIGH-PRESSURE FUEL PUMP
E. FILTER
F. RELIEF VALVE
G. FUEL PASSAGE
H. BYPASS VALVE

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Figure 5-25.—LM2500 fuel pump and system interrelation.

FUEL FLOW

Fuel supplied by the fuel oil service system flows through the base inlet connector to the fuel pump boost element. From the boost element it passes through the pump HP element. Then it goes through a pump-mounted simplex filter to the MFC. A filter bypass valve allows fuel to bypass a clogged filter.

The fuel pump has a higher flow capacity than the gas turbine uses to assure an adequate supply of fuel for gas turbine operation. The fuel is divided within the control into metered flow and bypass flow. This division is done by a bypass valve as it maintains a preset pressure drop across the metering valve. Bypass fuel is ported to the HP element inlet screen of the fuel pump. An abnormal condition can occur that causes pump outlet pressure to become too high. To correct this condition a relief valve in the pump bypasses fuel back to the HP element inlet screen.

A pressurizing valve is mounted on the fuel control outlet port. It maintains back pressure to ensure adequate fuel pressure for control servo operation. Two electrically operated fuel shutdown valves connected in series provide a positive fuel shutoff. When the fuel shutdown valves are open, metered fuel for gas turbine operation flows from the fuel control. It then flows through the pressurizing valve, shutdown valves, fuel manifold, and fuel nozzles. When the fuel shutdown valves are closed, metered fuel is bypassed to the fuel pump inlet. Then the fuel drain ports in the valves open to allow fuel in the manifold, nozzles, and lines to drain. Thirty fuel nozzles project through the compressor rear frame into the combustor. They produce an effective spray pattern from start to full power.

FUEL PUMP

The fuel pump (figure 5-25) has a centrifugal boost element and an HP gear element. It provides mounting pads and flange ports for the fuel filter and the MFC. As mentioned above, the filter bypass valve will allow fuel to bypass a clogged filter.

MAIN FUEL CONTROL

The MFC (figure 5-26) has two primary functions. One is to control GG speed (schedules

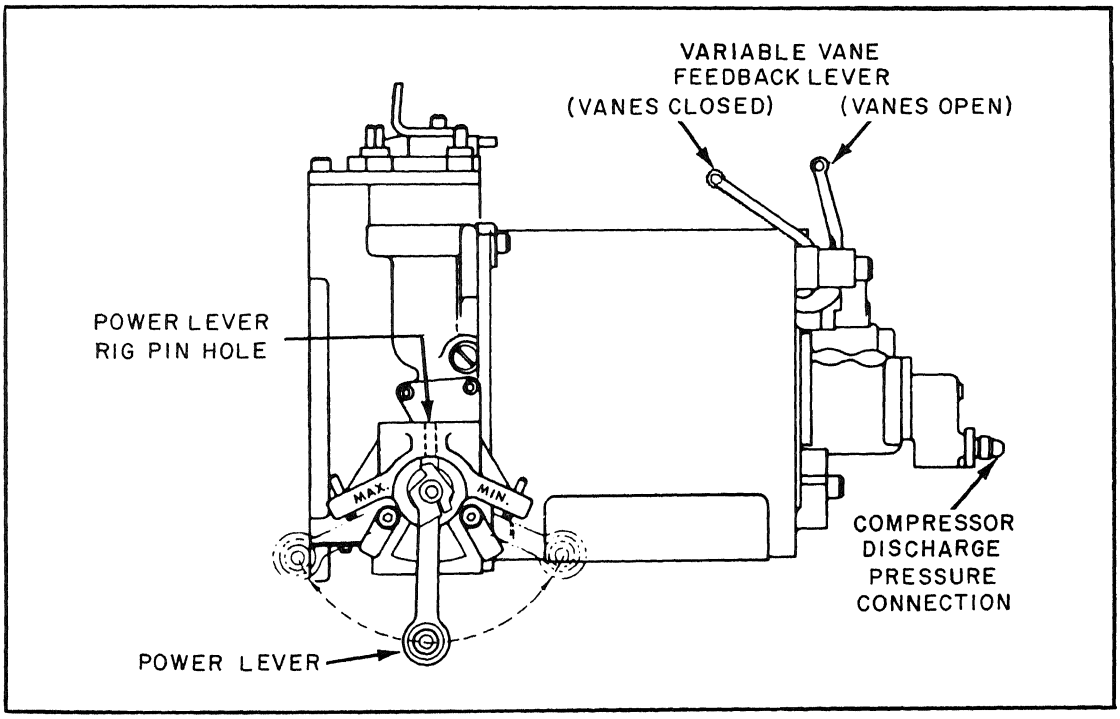

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Figure 5-26.—Main fuel control.

acceleration fuel flow, deceleration fuel flow). The other controls stator vane angle (for stall-free, optimum performance over the operating range of the gas turbine).

The MFC controls GG speed as a function of power lever position. The power lever is set electrically by a signal from the FSEE. Movement of the power lever changes speed demand. GG speed is sensed by means of a flyweight governor. This adjusts the fuel flow as necessary to maintain the speed set by the power lever. Three fuel schedules are established by the control: acceleration, deceleration, and minimum fuel schedules. The acceleration schedule limits fuel flow necessary for acceleration to prevent overtemperature and stall. The deceleration schedule limits the rate of fuel flow decrease to prevent combustion flameout during deceleration. The minimum fuel schedule limits fuel flow for starting to prevent overtemperature. The control senses CIT, CDP, and engine speed (N_{GG}). This biases the fuel schedules as a function of atmospheric and engine operating conditions.

The MFC schedules the VSVs as a function of GG speed and CIT. Actual position of the VSVs is sensed by the control via a position feedback cable. One end of the feedback cable is connected to the left master lever arm. The other end is connected to the feedback lever on the MFC.

PRESSURIZING VALVE

The pressurizing valve pressurizes the fuel system. This provides adequate fuel control servo supply pressure and VSV actuation pressure. This is necessary for proper fuel and stator vane scheduling during GG operation at low fuel flow levels. The valve is a fuel pressure-operated, piston-type valve. The piston is held on its seat (closed) by spring force and fuel pressure (reference pressure) from the MFC. Servo pressure is 110 to 275 psig. MFC discharge fuel (metered fuel for combustion) enters the pressurizing valve at the opposite side of the piston. When MFC discharge pressure is 80 to 130 psig greater than reference pressure, the valve opens. Thus, the upstream pressure (including servo supply and stator actuation) is 190 psig or greater before the pressurizing valve opens. This is adequate for proper operation.

FUEL SHUTDOWN VALVES

The fuel shutdown valves are pilot-valve actuated and electrically controlled. The valves are piped hydraulically in series. They are electrically operated in parallel by control logic during an automatic sequence. You can manually operate them from a local control panel during a manual stop. Both valves must be energized to port metered fuel to the GG fuel manifold. De-energizing either valve will bypass the fuel back to the pump inlet. Normally, both valves are de-energized to shut down the engine. The second valve acts as a backup and will bypass fuel if the first should fail to function. You can operate the two valves independently from the local operating panel (LOP) as a maintenance check. The fuel manifold system is shrouded. (The manifold and the manifold-to-fuel nozzle connector tubes are tubes within a tube assembly.) If a fuel leak develops in the manifold system, the leakage collects inside the shroud. It is then drained through a drain line to a telltale drain under the enclosure base. Next it goes to a collection tank. Thus, fuel leakage inside the enclosure from the manifold system is prevented and fire hazard is minimized.

COMPRESSOR INLET TEMPERATURE SENSOR

The CIT sensor consists of a constant-volume, gas-filled probe and a metering valve. This sensor controls or meters fuel across an orifice. It is mounted at the 8 o'clock position in the compressor front frame. The sensing probe projects through the frame into the airstream. Since the temperature sensing probe has a constant volume, the gas pressure inside the probe is equal to the temperature. This pressure is connected to a sensing bellows, which, in turn, is connected to the metering valve. Fuel from the MFC enters the CIT sensor. There it is metered by the metering

valve proportional to the temperature at the sensing probe. It is then used as a scheduling parameter by the MFC.

VARIABLE STATOR VANE ACTUATORS

The VSV actuators are single-ended, uncushioned hydraulic cylinders. They are driven in either direction by HP fuel. Piston stroke is controlled by internal stops. The actuators are mounted on either side of the compressor stator forward flange at the 3 and 9 o'clock positions. They are connected to the VSVs through master lever arms and actuation rings. The MFC schedules HP fuel to either the head end port (opens VSVs) or the rod end port (closes VSVs). The MFC senses several parameters to schedule variable vane angle. These are N_{GG}, CIT, and stator vane angle. A feedback cable is connected on one end to the left master lever arm and on the other end to the MFC. It inputs stator vane angle.

FUEL PURGE VALVE

The purge valve is an electrically operated, normally closed, on-off valve. It is used to drain low-temperature fuel from the system before gas turbine start. You can operate it by control logic during an automatic sequence or manually when a purge is required.

FUEL NOZZLES

The LM2500 uses 30 fuel nozzles to admit fuel to the combustor. These nozzles were discussed in depth earlier in this chapter. Refer to the section on the combustor for a complete description of fuel nozzles.

FUEL MANIFOLD PRESSURE TRANSDUCER

The fuel manifold pressure transducer is used to input the fuel manifold pressure into the FSEE. This input is used to display the pressure at the operating consoles.

The transducer is a 0 to 1500 psig model. It is located under the module on the baseplate. Fuel is supplied to the transducer from the fuel line leading to the fuel manifold. This is a standard-type transducer like that described in chapter 3.

LUBE OIL SYSTEM

The lubrication system (figure 5-27) provides the gas turbine bearings, gears, and splines with adequate cool oil. This prevents excessive friction and heat. The synthetic lube oil used in this application is MIL-L-23699. The lubrication system is a dry sump system. It is divided into three subsystems that have three functions identified as lube supply, lube scavenge, and sump vent.

The lube oil system contains several components which perform the functions of the subsystem. These components are the lube and scavenge pump, the supply filter, the supply check valve, and the C and D sump supply check valves. These units are all mounted either on the engine or in the enclosure. Some components are mounted on the lube oil storage and conditioning assembly (LOSCA) (figure 5-28). These units are the oil tank, oil cooler, scavenge oil filter, scavenge oil check valve, filter differential pressure transducer and gauge, level sensor, and temperature switch.

LUBE OIL FLOW

Lube oil is gravity fed from the LOSCA through the ship's piping to an inlet fitting in the enclosure base. It is then fed to the inlet of the supply element of the lube and scavenge pump. From the supply element of the pump, the oil passes through the supply duplex filter. It then goes through a check valve and into a supply manifold. From the supply manifold, the oil is distributed to the four sumps and the transfer gearbox. Each end of the sump has a labyrinth/windback oil seal and a labyrinth air

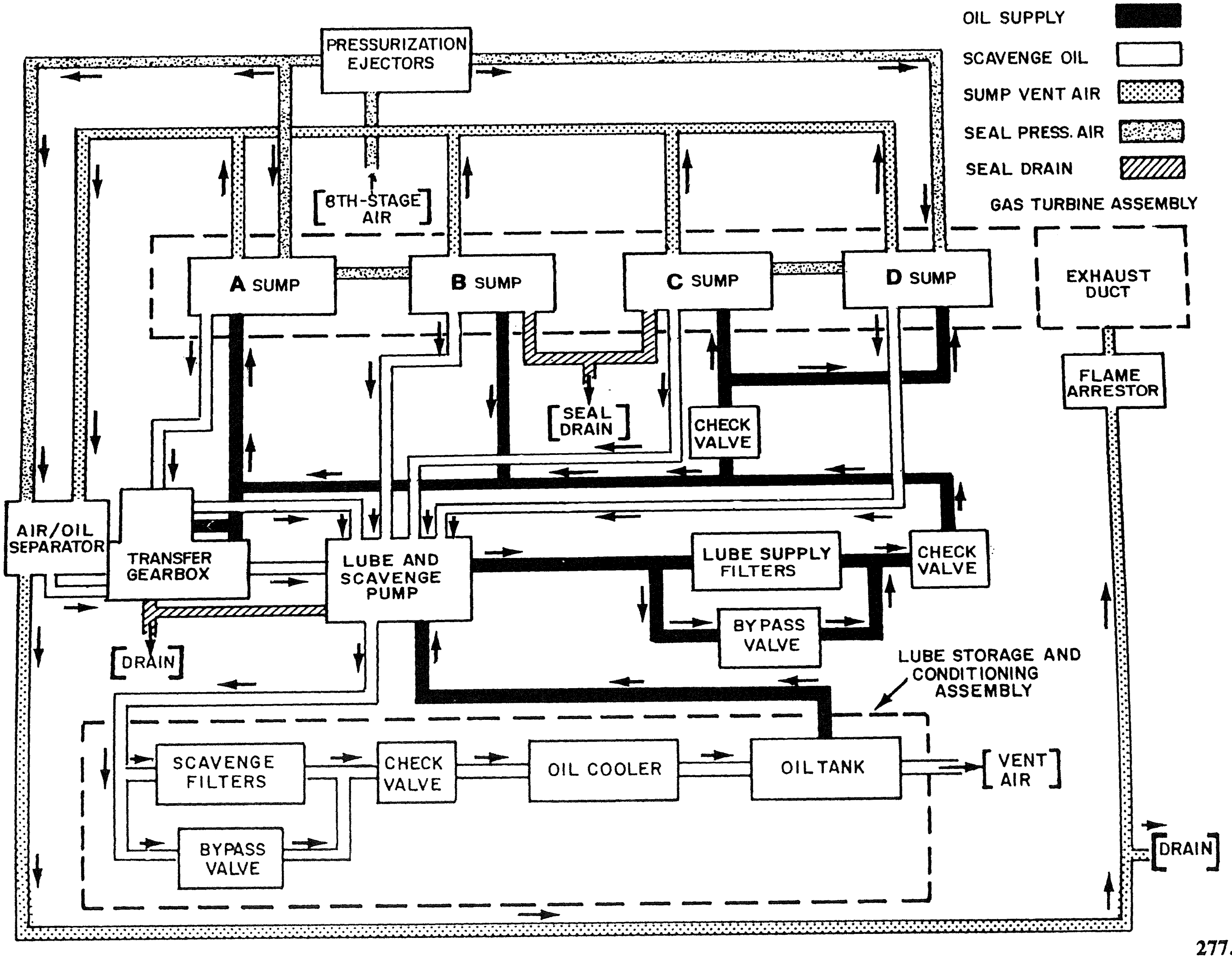

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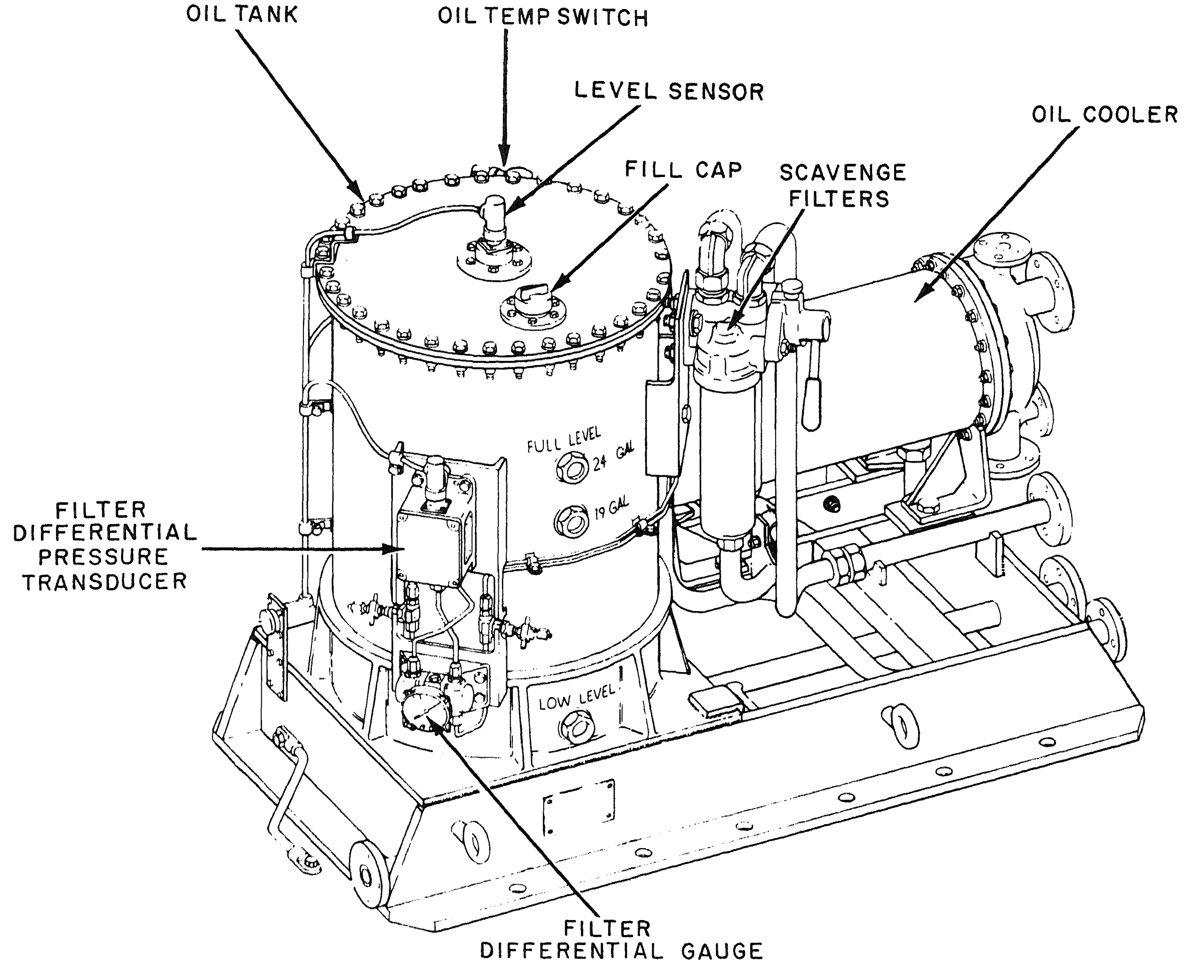
Figure 5-27.—LM2500 lube oil system block diagram.



277.27.1

Figure 5-28.—Lube oil storage and conditioning assembly.

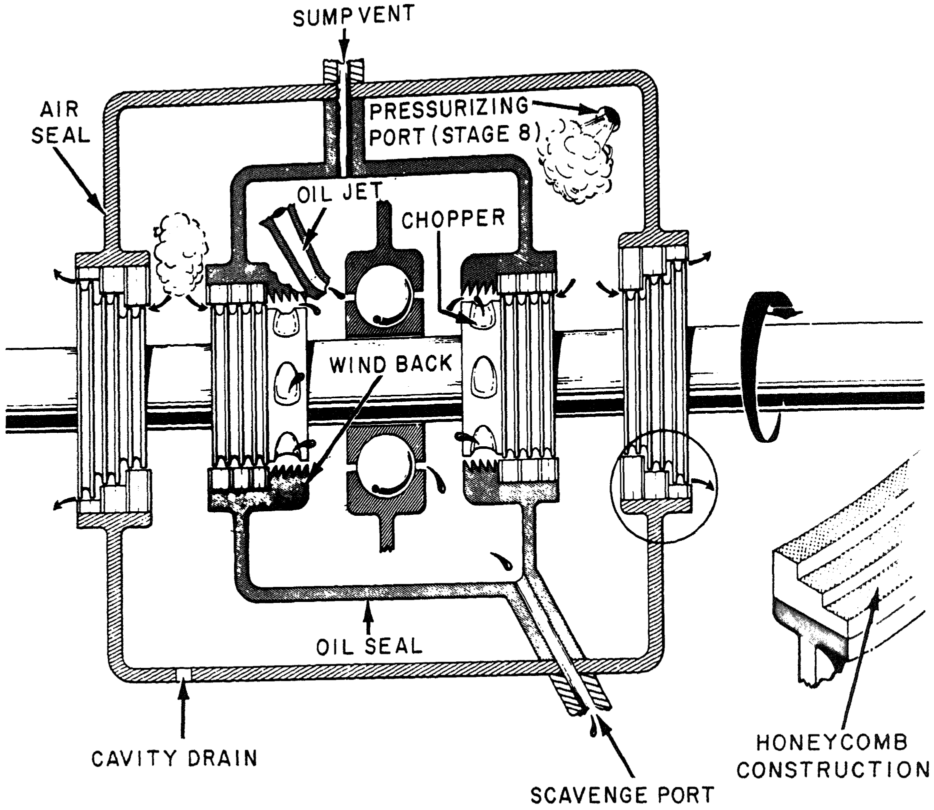
seal (figure 5-29). This is to prevent oil leakage from the sumps. The cavity between the two seals is pressurized from aspirators (air ejectors), which are powered by eighth-stage air. The pressure in the pressurization cavity is always greater than the pressure inside the sump. Therefore, air flowing from the pressurization cavity, across the oil seal, prevents oil from leaking across the seal.

The scavenge oil is drawn in from the sumps and transfer gearbox by the five scavenge elements of the pump. It passes through the pump, through an outlet fitting on the enclosure base, and is returned to the LOSCA.

At the LOSCA the oil passes through the scavenge filters to the scavenge check valve. It then goes through the heat exchange. The heat exchange uses MRG (2190 TEP) lube oil to cool the MIL-L-23699. The cooled oil is then routed to the oil tank for storage and deaerating.

LUBE OIL SYSTEM COMPONENTS

In the following paragraphs we will describe the eight lube oil system components. They include the lube and scavenge pump, the lube supply filter and check valve, the C and D sump check valve, the scavenge oil filter and check valve, the heat exchanger, and the oil tank.



293.42

Figure 5-29.—Bearing sump principles.

Lube and Scavenge Pump

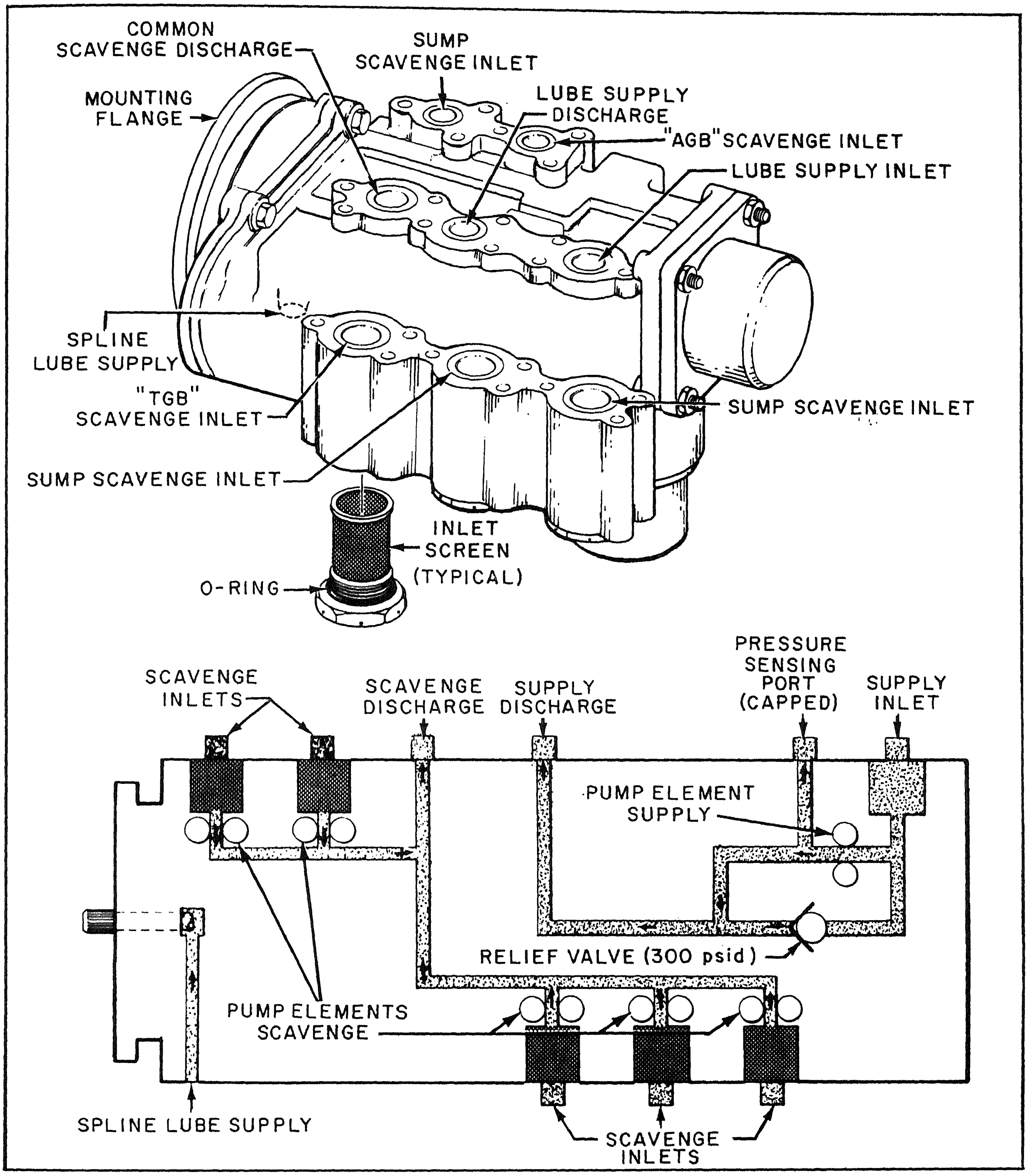
The lube and scavenge pump (figure 5-30) is a six-element positive-displacement vane type of pump. One element is used for lube supply; five are used for lube scavenging. Within the pump are inlet screens, one for each element, and a lube supply pressure limiting valve. The outputs of the five scavenge elements are connected inside the pump and discharge through a common scavenge port.

Lube Supply Filter

The lube supply filter is a duplex type which allows for manual selection of either element. Filtration is 74 microns (nominal). A relief valve in the filter will open to allow oil to bypass a clogged filter. You select filters by raising a spring-loaded locking pin. Then move the selector handle until it is in front of the element not to be used. You then release the locking pin, making certain that the pin is engaged in the locking slot. A drain plug is located in the bottom of each filter bowl. It permits you to drain oil from the element before removal for cleaning.

Lube Supply Check Valve

The lube supply check valve is located on the downstream side of the supply filter. It prevents oil in the tank from draining into the sumps when the gas turbine is shut down. It will open and flow 20 gallons per minute (gpm) with a maximum of



277.30

Figure 5-30.—Lube and scavenge pump.

15 pounds per square inch differential (psid) pressure.

C and D Sump Check Valve

This check valve is located in the lube supply line to the C and D sumps. It isolates the C and D sumps from the GG lube oil system when an external lube supply and scavenge system is used for the PT. The C and D sump oil supply and scavenge lines have fittings to allow the use of an external lube system for the PT. During normal engine operation, lube oil is supplied to the C and D sumps from the lube pump. The check valve opens at 2 psid pressure.

Scavenge Oil Filter

The scavenge oil filter is a duplex type identical to the supply filter described earlier in this section. The only difference is that filtration of the scavenge oil filter is 46 microns (nominal).

Scavenge Oil Check Valve

The check valve is located between the scavenge filter and the heat exchanger. It prevents oil in the scavenge lines from draining back into the sumps and gearbox during engine shutdown. The valve will open and flow 20 gpm with a maximum differential pressure of 15 psid.

Heat Exchanger

The heat exchanger (oil cooler) is a shell-tube assembly. The coolant, MRG lube oil, passes from the MRG lube oil cooler through temperature control valves. It then flows through the inside of the tubes. The synthetic lube oil passes around the outside of the tubes. You remove the end domes for direct access to clean the inside of the coolant tubes.

Oil Tank

The oil tank (figure 5-28) has sight glasses for visual determination of oil level in the tank. An oil level switch monitors oil level from within the tank. It transmits a signal when the system level is too high or too low. The tank is considered full when it contains 24 gallons. Mounted on the tank are instrumentation valves, a filter differential pressure transducer, a filter differential pressure gauge, and an oil temperature sensor. Baffles, located in the bottom of the tank, minimize oil sloshing. Inside the tank at the scavenge inlet is a deaerator. It separates air from the scavenge oil and vents the air through the oil tank vent. A gravity fill port is located on the tank cap. A drain valve is located in the assembly base.

AIR INTAKE SYSTEM

The air intake system for the LM2500 provides the large quantity of air needed for engine operation. The design of the ducting varies with the classes of gas turbine ships. But they all provide the same functions. The intake system reduces the flow distortion, pressure drop, and salt ingestion. The intake system also provides duct silencing, a supply of cooling air, anti-icing protection, and a route for engine removal.

DD-963, DDG-993, AND CG-47 INLET DUCT SYSTEMS

The inlet duct systems for the DD-963, DDG-993, and CG-47 classes of ships are very similar. The only major difference is the sand separators used on the DDG-993 class. Since these occur on only four ships, we will not discuss them in this book.

Overall Flow Description

Refer to figure 5-31 while you are reading this section. It shows the intake duct system of the DD-963 and CG-47 classes of ships. Intake air enters the main duct through the moisture separator. This is located in the sides of the high hat inlet. The air flows down the main duct and passes through silencers located about midway down the duct. It then flows through a flexible coupling into the engine inlet plenum. Cooling air is taken off the main duct ahead of the silencers. It flows through the cooling duct, cooling duct silencers, and cooling air fan. It then enters the engine enclosure through a vent damper. The air circulates around the engine and exits the enclosure through the exhaust plenum.

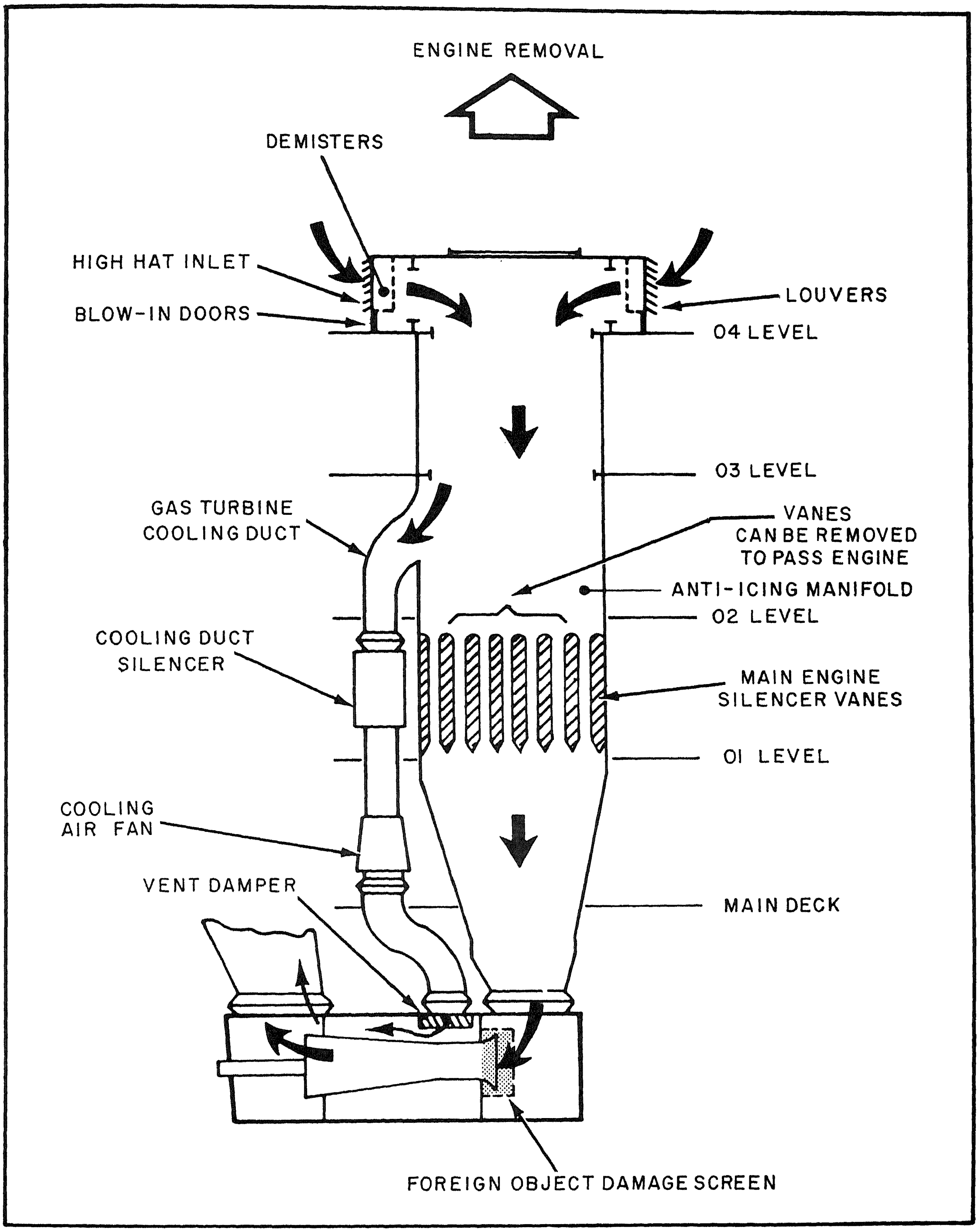


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Figure 5-31.—Intake duct system, DD-963, and CG-47 classes.

If the moisture separation system becomes blocked, the blow-in doors open. These are located below the inlet louvers. They automatically open to supply the engine with combustion and cooling air. In this mode of operation there is no demisting protection.

High Hat Assembly

The high hat assembly (figure 5-32) is located on the 04 level of the ship. It contains the moisture separation system and the blow-in doors.

MOISTURE SEPARATION SYSTEM.—The moisture separation system includes the inlet louvers and the demisters. The inlet louvers are arranged in sections. They are located in the sides of the high hat assembly. The design and arrangement of the louvers are such that they shed spray. The louvers are electrically heated to prevent icing. These heaters are strip type and are located on the back of the louver surface. The heaters are controlled from the engine control consoles. The demisters are two-stage mesh-pad type mounted vertically behind the louvers. Water, separated from the inlet air as it passes through the demisters, is collected in scuppers and is drained overboard. Demister performance is shown below:

Particle Size	Removal Efficiency
5 microns and larger	90%
1.7 microns to 5 microns	70%

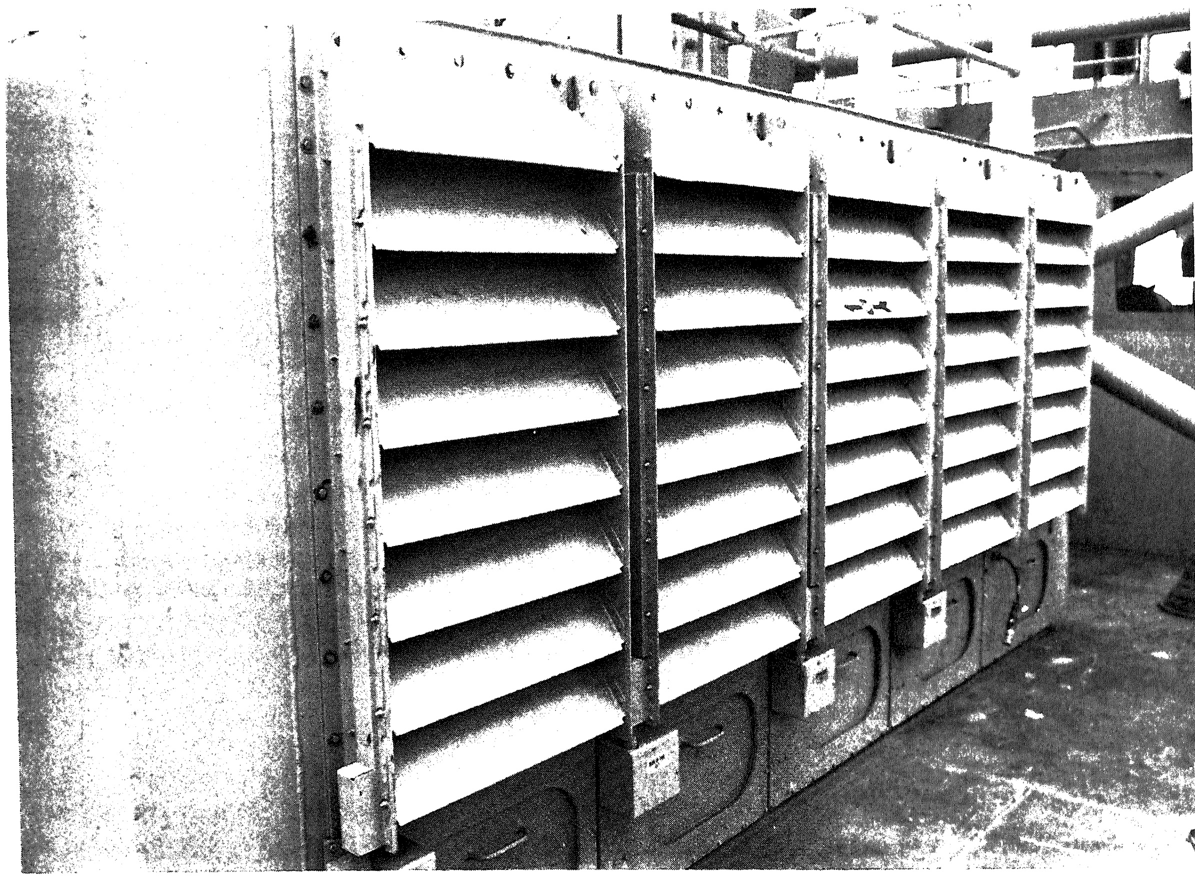

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Figure 5-32.—DD-963 type of blow-in doors and louvers.

BLOW-IN DOORS.—The blow-in doors are located just below the inlet louvers. They are designed to open by solenoid-operated latch mechanisms. They open if the inlet airflow becomes too restricted for normal engine operation. Their function is to bypass the moisture separation system. They provide an unrestricted inlet airflow to the engines if the moisture separation system becomes blocked.

A controller is located in each engine room to provide for manual or automatic operation. This is done by a selector switch and a pushbutton on the controller door. On the CG-47 class this controller is in the helo hangar. The pushbutton on the CG-47 class is located on the high hat assembly. In manual operation, you can only open the doors by depressing the pushbutton. In automatic operation, you can only open the doors by operation of a pressure switch. The switch operates on low duct pressure. This pressure switch also provides a DUCT PRESSURE LOW signal to propulsion auxiliary machinery control equipment (PAMCE) and propulsion local control equipment (PLOE). The pressure switch operates when duct pressure falls below 8 inches of water. Once tripped, you must manually reset the doors closed.

Ducting

The ducting allows the air to travel from the high hat assembly to the inlet of the compressor. The components of the ducting include the silencers, the anti-icing piping, the cooling air duct, and the engine removal system.

SILENCERS.—The main engine intake duct silencers are located about halfway down the duct. The silencers are vertical vane assemblies consisting of sound-deadening material. It is encased in perforated stainless steel sheet. The vanes are arranged in modules which are removable. This permits removal of the GTEs through the intake duct.

ANTI-ICING PIPING.—This system prevents the formation of ice in the intake duct. High-temperature bleed air from the GTEs is piped to a manifold. This manifold is located inside the duct between the cooling air extraction port and the silencers. From the manifold the bleed air is discharged into the inlet airstream. The air is mixed with the inlet air, raising the temperature enough to prevent the formation of ice. When enabled from PLOE or PAMCE, an electromechanical control system regulates bleed air flow. This controls the inlet air temperature to 38 °F nominal, enough to prevent the formation of ice. It also melts away built-up ice or snow, regardless of dew point. A temperature sensor in the stack provides an ANTI-ICING INSUFFICIENT signal. This tells when the anti-icing system has been enabled and the temperature drops below 36 degrees.

COOLING AIR DUCT.—Main engine cooling air is extracted from the main intake duct. It is taken at a point between the blow-in doors and the main duct silencers. It is then ducted to the engine enclosure. The cooling air duct contains a silencer and a cooling air fan. The cooling system will be discussed in more depth later in this chapter.

ENGINE REMOVAL SYSTEM.—It may become necessary to remove a propulsion engine from the ship for maintenance/overhaul. If so, the engine is removed through the intake duct. At the time of engine removal, a set of channel-shaped maintenance rails is installed in the engine enclosure. These are put adjacent to each side of the engine. A set of rollers, which fit into the rails, is attached to each side of the engine. The removable maintenance rails extend into the enclosure inlet plenum. They then turn 90 degrees, from horizontal to vertical attitude. They mate with permanently installed rails that extend up the intake duct. In the inlet plenum, three sets of maintenance rails interface with three sets of permanently installed rails in the ship's intake duct. The permanently installed rails extend through the high hat section. These serve to guide the engine as it is lifted vertically from the ship.

Removal of the engine is accomplished in two operations. The GG is separated from the PT while still in the enclosure. The GG is then removed from the ship first, followed by removal of the PT.

FFG-7 INLET DUCT SYSTEM

The gas turbine uptake and intake system consists of three separate ducting systems (figure 5-33). They are for combustion air, cooling air, and exhaust gas elimination. Atmospheric air for the combustion and cooling air ducting normally enters through the intake plenums (figure 5-34). These are located on each side of the ship's structure. The air is then carried through ducting to the GTMs in the engine room below. Ducting connections to the GTMs are made via expansion joints on top of each GTM. The combustion air intake ducts also provide the access for removal and replacement of the engine GG and PT sections.

Besides the ducting, the gas turbine uptake and intake system includes moisture separator assemblies, emergency inlet doors, and cooling air fans. Also included are cooling air bypass dampers and provisions for anti-icing upstream and downstream of the moisture separators.

Moisture Separators

The moisture separators are of knit wire mesh construction mounted in a supporting frame. They remove moisture droplets containing sea salt. They also prevent other foreign objects from entering the intake and cooling air ducts. In operation, the moisture droplets adhere to the wire mesh while the air passes through. The moisture droplets coalesce into larger drops and fall free of the airstream. They then drain into troughs which are piped to the plumbing drains system. There are eight panels of moisture separators for each combustion air intake duct. There are four panels for each cooling air duct.

Emergency Inlet Doors

Emergency inlet doors are provided in the combustion air and cooling air ducts to each engine. One emergency inlet door is located between the uptake space and each combustion and cooling air duct. If the moisture separators start to ice or are partially blocked for any reason, the emergency inlet doors will open. These open automatically to provide inlet air from the uptake

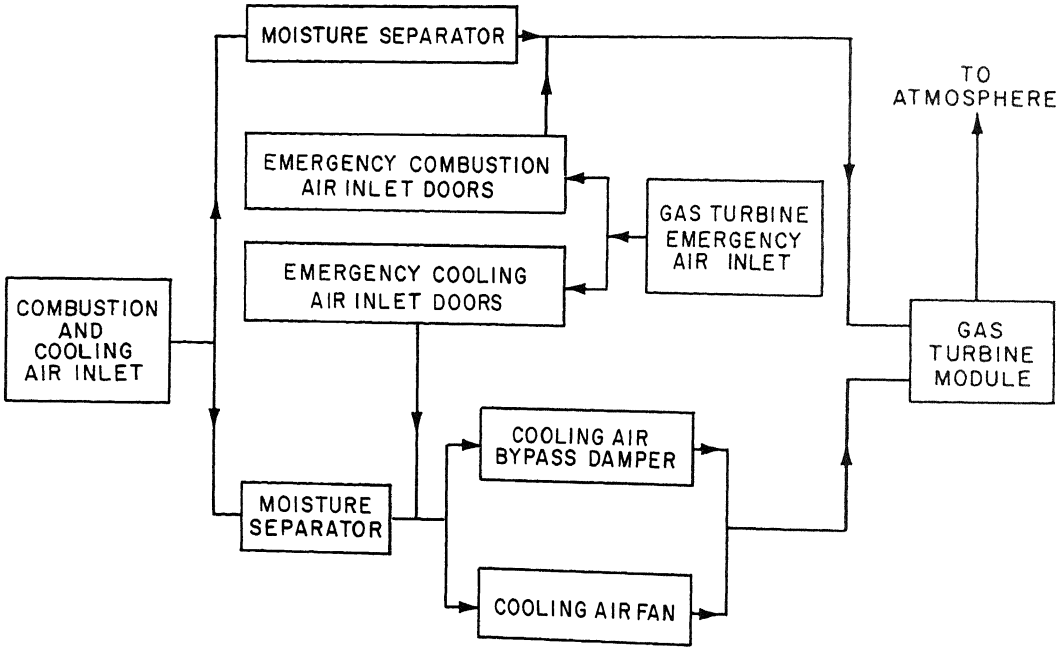

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Figure 5-33.—Block diagram of FFG-7 air intake system.

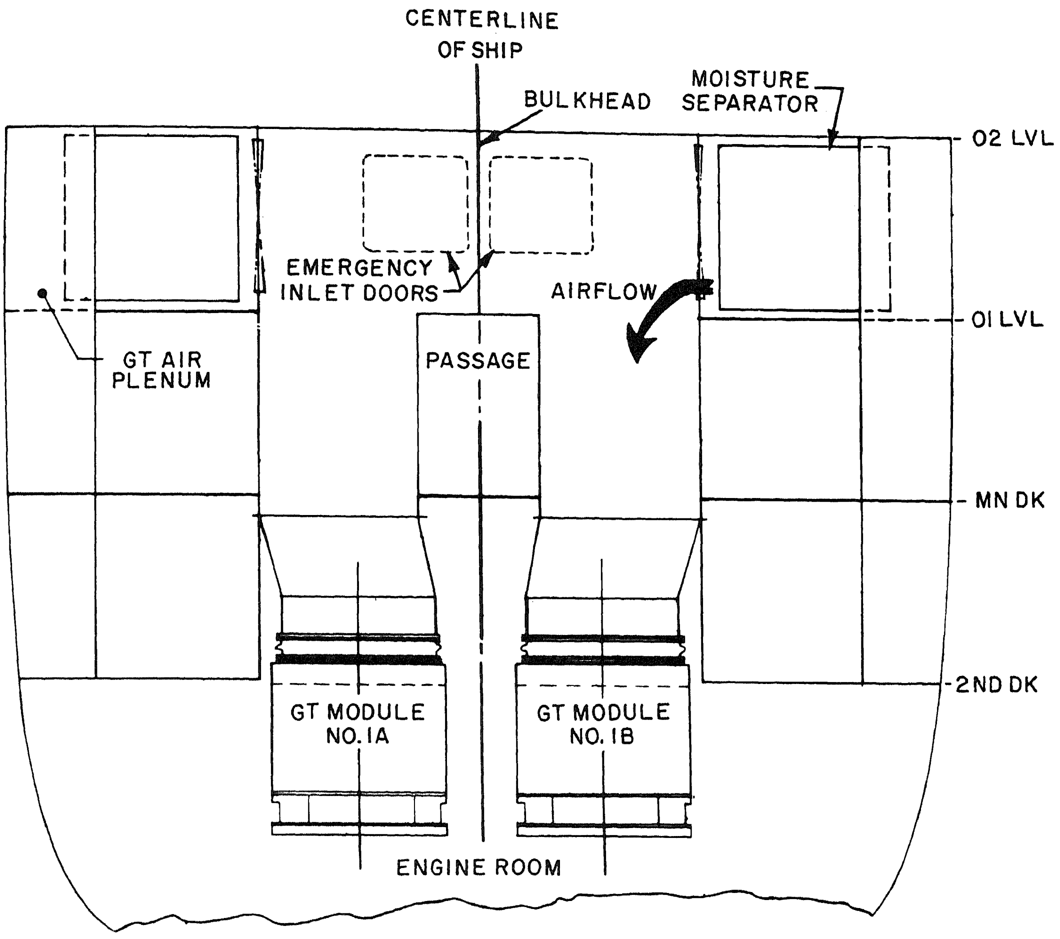

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Figure 5-34.—FFG-7 class air intake system.

space and permit continued limited power engine operation. The doors are pneumatically actuated and automatically controlled by differential pressure switches. Each combustion air emergency inlet door opens automatically at a differential pressure of 9.0 inches of water. The cooling air emergency inlet doors open automatically at 3.0 inches of water differential pressure. You can actuate each door manually using the air solenoid override at the door control panel. You can also open them manually using a wrench at the door assembly.

Anti-Icing System

An anti-icing system uses bleed air from the GT. It is used to prevent the formation of ice in the intake system. Anti-icing nozzles are located upstream and downstream of the moisture separators.

Bleed air from each GG is piped to its associated intake system for anti-icing purposes. The piping to each intake system contains a 250/38 psig regulating valve to reduce the bleed air pressure. The bleed air supplied to the intake system provides anti-icing air for the moisture separators, the GG bellmouth, and the enclosure cooling fan. Bleed air also supplies the cooling air bypass damper and the enclosure cooling air damper.

The anti-icing pressure regulating valve is actuated from either the propulsion control

console (PCC) or the LOP. Valve status indication is provided at both control stations.

Intake Monitoring and Control

Outside air temperature is sensed by an RTD. It is mounted in each intake plenum upstream of the moisture separators. The temperature is displayed on the PCC demand display and on an edgewise meter on the LOP. The temperature signal is used by the propulsion control system (PCS) for gas turbine enclosure ventilation damper logic. It is also used for automatic GT power correction when operating in programmed control. A differential pressure sensor measures the pressure difference between the intake duct and outside atmospheric pressure. If the differential pressure exceeds 7.5 inches of water, the combustion air intake LP alarm is activated on the PCC in the central control station (CCS). This parameter can also be demand displayed on the PCC.

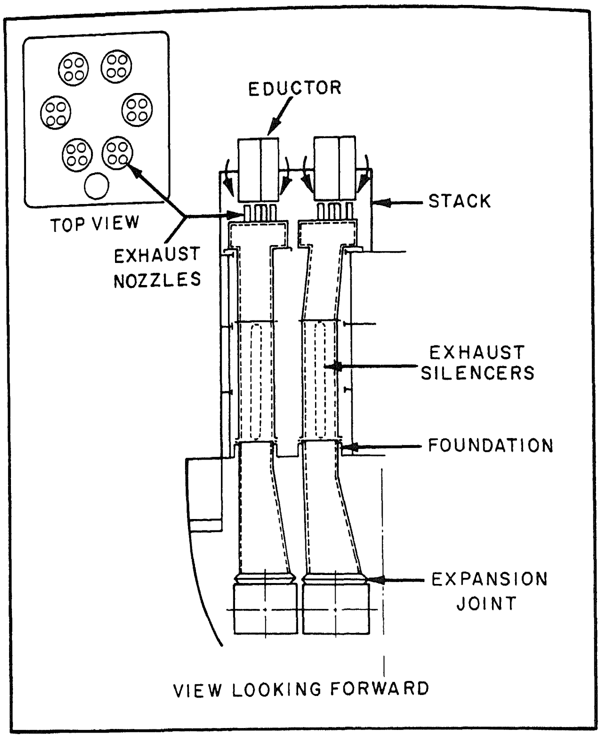

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Figure 5-35.—DD-963/DDG-993 exhaust duct system.

EXHAUST SYSTEM

The gas turbine exhaust system expels the exhaust by preventing reingestion of the exhaust gases. This system also minimizes the sound and the heat sensing of the ship by hostile vessels and aircraft. Reingestion of the exhaust gases is prevented by having the exhaust stack higher than the air inlet ducts. Sound level is reduced by exhaust duct wall insulation. On some ship classes a silencer is installed to assist in noise reduction. Exhaust heat is reduced by combining the module cooling air with the hot gases. Exhaust gas temperature may be further reduced by an IR suppression system.

DD-963/DDG-993 CLASS EXHAUST SYSTEM

These ship classes employ silencers and a saltwater-cooled IR suppression system. A DD-963/DDG-993 type of exhaust system is shown on figure 5-35.

Silencers

A single vane type of silencer is located in the center of the duct. It has sound-deadening material encased in perforated stainless steel sheet. This and duct wall insulation reduce the sound level enough to meet the airborne noise requirements.

Eductors

The exhaust eductors are located at the top of each propulsion engine exhaust duct. They mix outside air and the IR suppression spray with the turbine exhaust gases before releasing them into the atmosphere (figure 5-36). The eductor is basically a mixing tube which protrudes from the exhaust stack top. It is positioned so the gas flow from the exhaust nozzles will draw outside air into the exhaust stream. It also draws IR suppression spray into the exhaust as it enters the mixing tube.

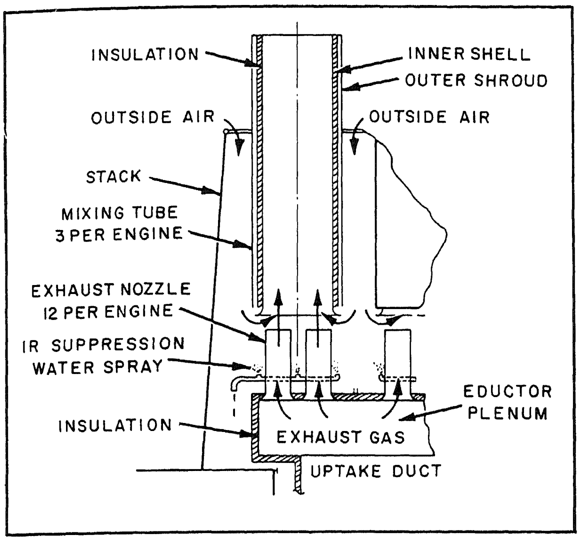

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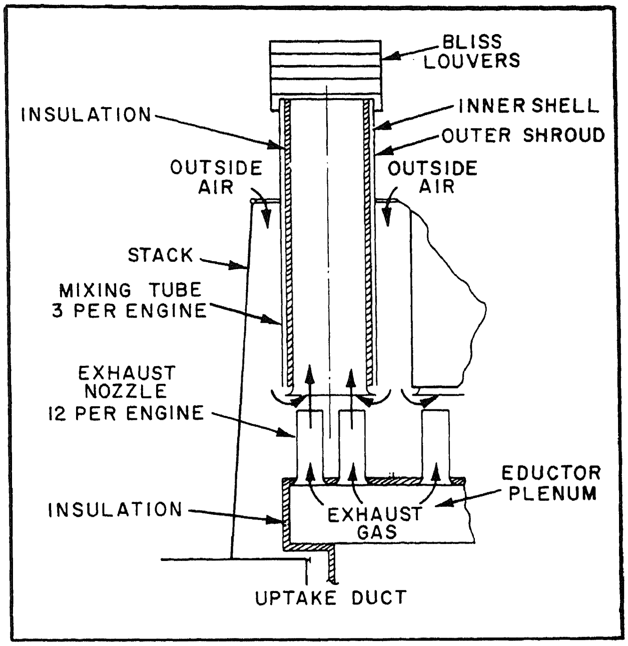
Figure 5-36.—DD-963/DDG-993 exhaust eductor.



286.26.2

Figure 5-37.—CG-47 class exhaust eductor.

Infrared Suppression

The propulsion engine IR suppression system reduces exhaust gas temperature. It does this by injecting a seawater spray into the exhaust stream before it leaves the eductors. Below each eductor mixing tube is a water spray ring manifold. This encircles the associated four exhaust nozzles (figure 5-36). It gives a total of six spray manifolds for each of the two main engine exhaust stacks. Seawater is pumped up to the eductors from the firemain water system. It is then sprayed vertically upward from the spray manifolds. The spray is drawn into the eductor tube by the exhaust streams. The fresh airflow mixes with the gases before leaving the stacks.

CG-47 CLASS EXHAUST SYSTEM

The CG-47 exhaust system is similar to the DD-963/DDG-993 class with only one major exception. On the CG-47 class the IR suppression system has been replaced with a boundary layer IR suppression system (BLISS) (figure 5-37). This system is comprised of a series of eductors at the top of each exhaust stack. BLISS is in continuous operation.

FFG-7 CLASS EXHAUST SYSTEM

The uptake system (figure 5-38) conducts the GT combustion exhaust gases and the enclosure exhaust air to the atmosphere. The exhaust trunk extends from the exhaust expansion joint at the enclosure, up through the ship. It terminates in the atmosphere above the top of the stack. The enclosure cooling air exhaust is drawn into the exhaust trunk through the action of an eductor at the top of the enclosure. An RTD is mounted in the exhaust trunk. It provides a signal to the propulsion control system for the demand display at the PCC of the exhaust temperature.

MODULE COOLING SYSTEM

Navy gas turbines are not rated for operation in high ambient temperatures above 130°F. A module cooling system must be used to prevent operation of the engine in temperatures greater than 130°F.

The LM2500 GTM uses a combination of fan-forced ventilating air and exhaust gas eduction to

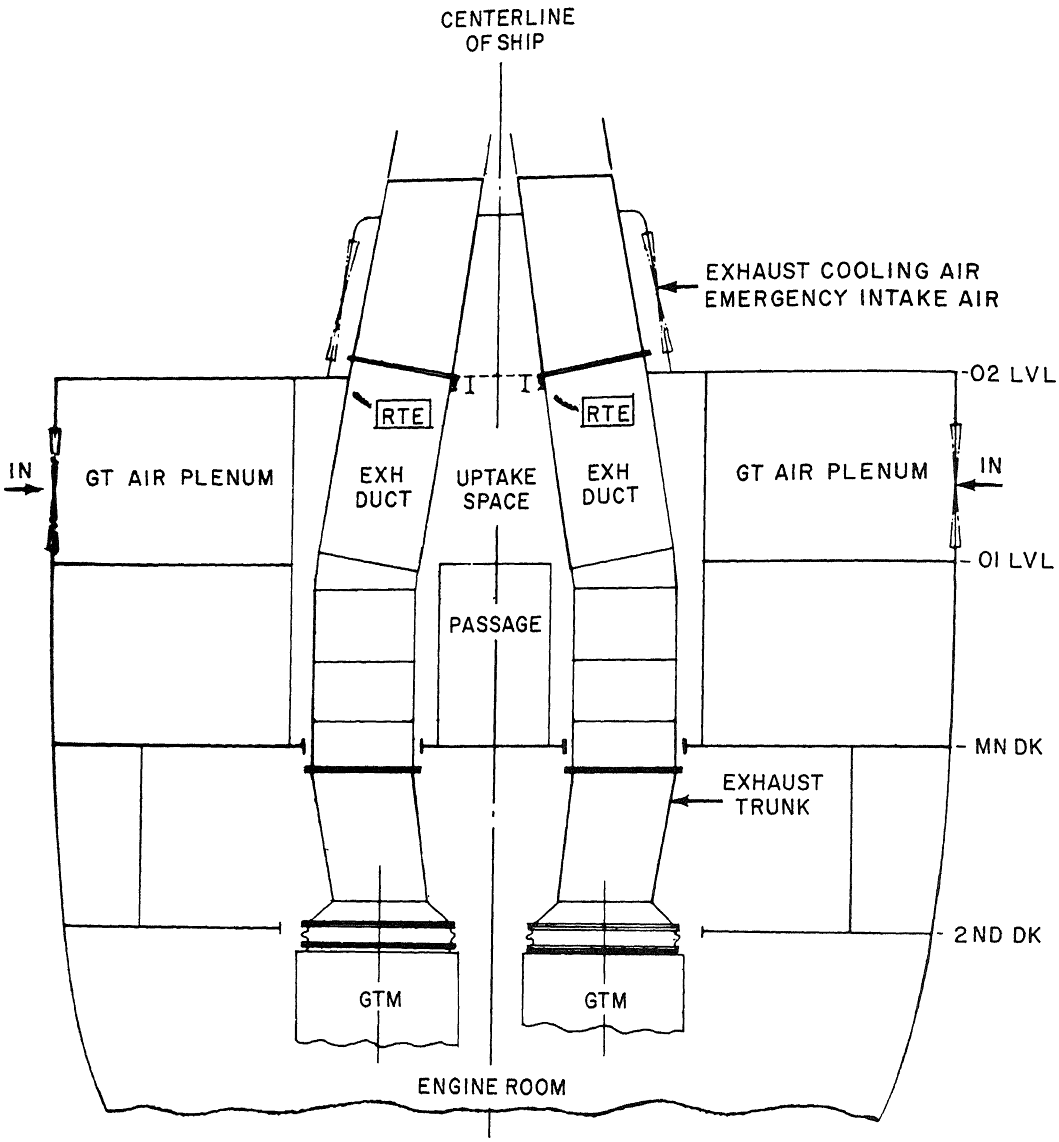


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Figure 5-38.—FFG-7 class exhaust system.

cool the GTM (figure 5-39). Cooling air is taken into the cooling duct and pressurized by the fan. It is then discharged at the ventilation damper on the top of the module. Once the air enters the module, a natural swirling effect takes place around the engine. The cooling air moves to the back of the module where it is removed by the exhaust eductor. Although the cooling systems of the different classes perform the same function, they are constructed differently. The following sections of this chapter describe these differences.

DD-963, DDG-993, AND CG-47 CLASS COOLING SYSTEM

Main engine cooling air is extracted from the main intake duct at a point between the blow-in doors and the main duct silencers. It is then

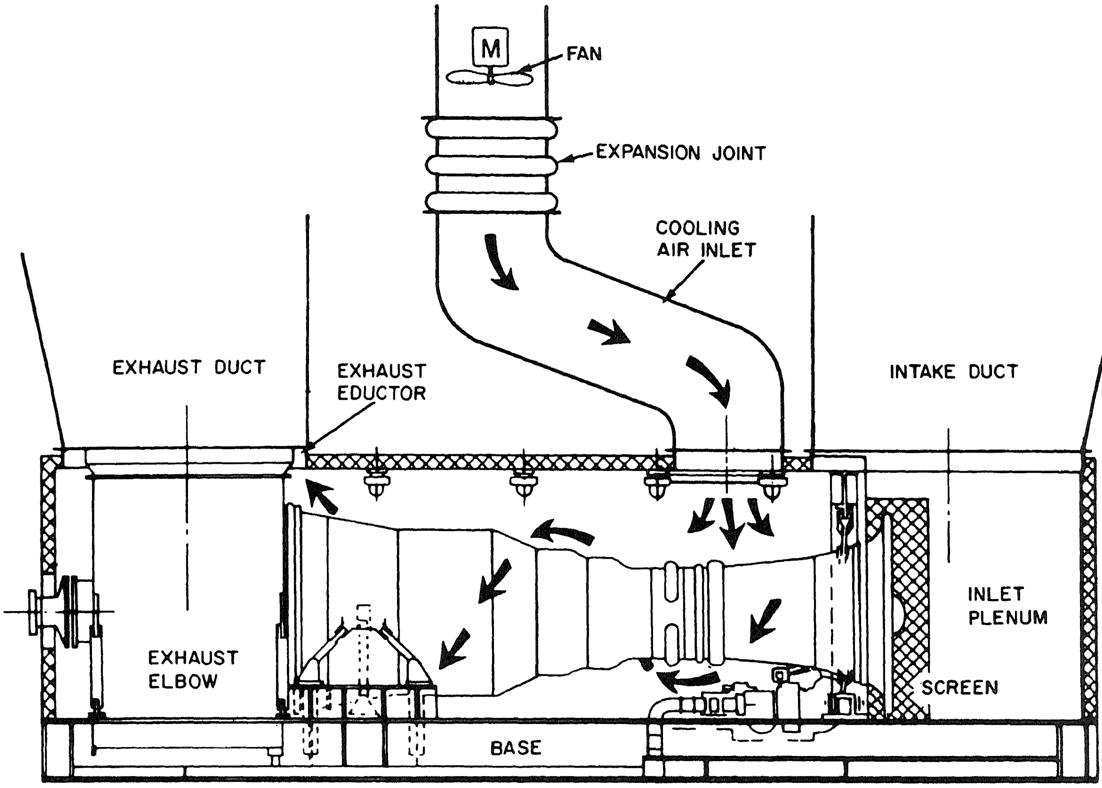

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Figure 5-39.—Gas turbine module cooling.

ducted to the engine enclosure. The cooling air duct contains a silencer and a cooling air fan. The silencer consists of a double-walled cylinder. The outer wall is solid sheet and the inner wall is perforated sheet. The space between is filled with sound-deadening material. Suspended in the center of the cylinder is a torpedo-shaped baffle. It is made of perforated stainless steel sheet filled with sound-deadening material. The silencer forms a section of the cooling air duct. The cooling air fan is located in the duct between the engine enclosure and the silencer. The fan is rated at 80 horsepower and flows air at 17,000 cubic feet per minute (ft^3/min).

From the cooling fan, the air is ducted to the engine enclosure. It enters the enclosure through a ceiling-mounted vent damper. Then it circulates around the engine. The air exits the enclosure through the exhaust plenum. The cooling is activated either manually or automatically from PLOE or PAMCE and must be running for engine operation. The vent dampers are electropneumatically operated. They use air from the ship's service air system (SSAS). The vent dampers are operable either automatically or manually from PLOE or PAMCE.

FFG-7 CLASS COOLING SYSTEM

The cooling air ducts to each engine are made up of two parallel sections (figure 5-40). One section contains a cooling air fan and the other a cooling air bypass damper. The two sections join together before connecting to the GTM. At low engine power the cooling air fan in one leg supplies cooling air to the GTM. This acts to close the bypass damper in the other leg. As the engine power level passes 3,000 shaft horsepower (SHP), the engine exhaust eductor creates enough draft for the bypass damper to open. Both parallel legs

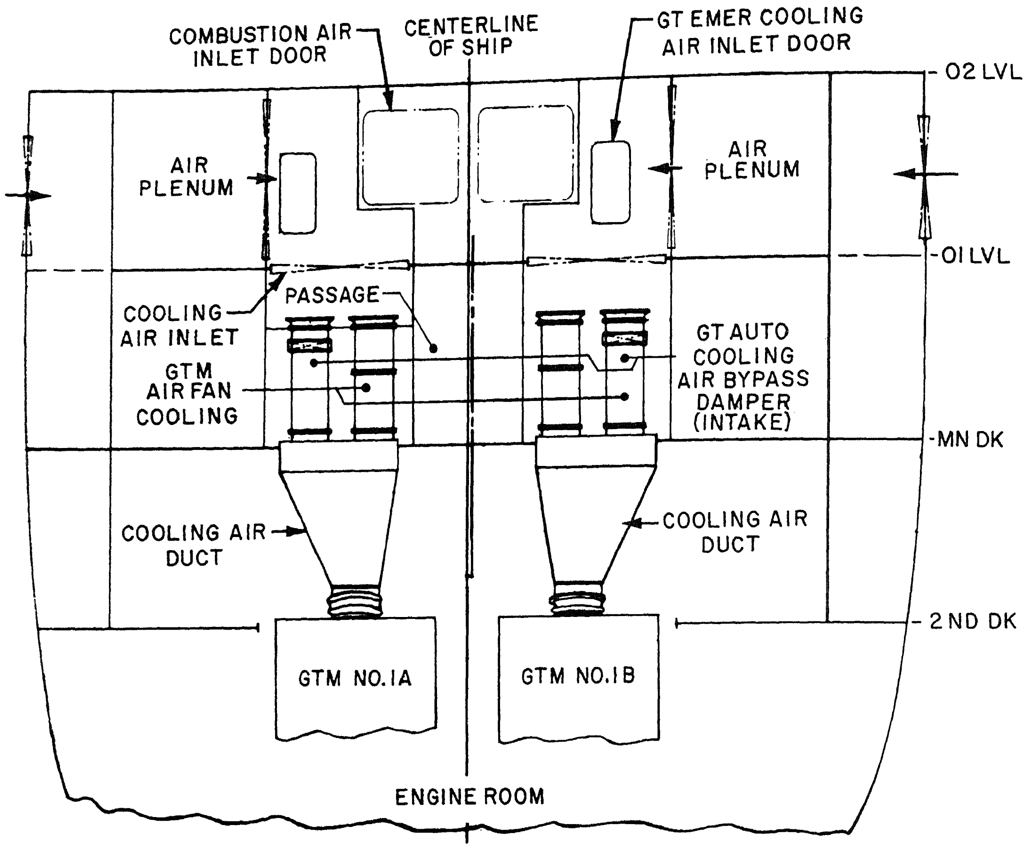

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Figure 5-40.—FFG-7 class cooling air system.

then permit cooling air to enter the GTM. The cooling air fan is shut off automatically at an engine power level of 3,000 SHP by the PCS.

The PCS provides the control and status indications for the cooling air fans at the PCC and the LOP. Both locations have controls for manually starting the fans. They also have automatic control of the fans after the GTs have been started. The fan local motor controller provides the only controls for stopping the fan in the manual mode. The cooling air bypass dampers have position switches that show the status of the bypass damper at the PCC.

STARTING AIR SYSTEM

The starting air system provides compressed air to rotate the engine starter through the accessory drive. The starter rotates the GG for starting, motoring, and water washing. The system uses either engine bleed air or HP air on the DD-963, DDG-993, and CG-47 classes. The FFG-7 class uses either engine bleed air or air from diesel driven start air compressors (SACs).

The start system (figure 5-41) has a pneumatic turbine starter and a starter valve. The starter is mounted on the aft side of the transfer (accessory) gearbox. The starter valve is line-mounted behind the starter. The starter drives the GG through the

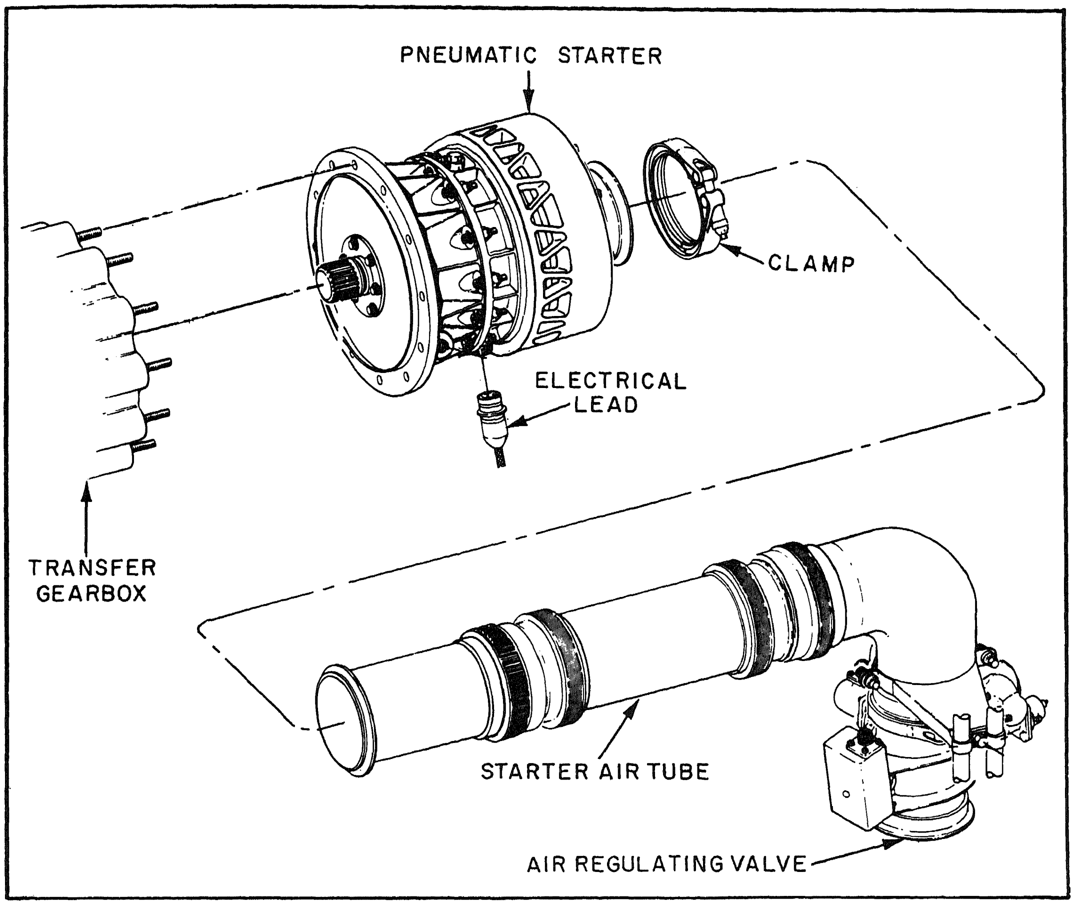

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Figure 5-41.—LM2500 air starting system.

gearbox during the start cycle. It drives it until the GG reaches or exceeds self-sustaining speed.

STARTER

The starter has an inlet assembly, a turbine assembly, and reduction gearing. It also includes a cutout switch, an overrunning clutch, and a splined output shaft. The turbine is a single-stage, axial flow type. The reduction gearing is a compound planetary system with a rotating ring gear. The overrunning clutch is a pawl and ratchet type. This provides positive engagement during starting and overrunning when driven by the GG. The cutout switch is normally closed. It is actuated by a centrifugal governor which trips open the switch. This also illuminates a STARTER CUTOUT indicator light at the propulsion consoles. The output shaft has a shear section to prevent overtorque damage. The starter operating air pressure is 35 to 41 psig for starting and 21 ± 1 psig for water washing. Air to the starter is piped from the starter air valve. The starter exhausts directly into the module enclosure.

STARTER VALVE

The starter valve is a normally closed pneumatic regulator and shutoff valve. It has a bleed-on regulator, a solenoid switcher, and a pneumatic switcher. It also incorporates a check valve, an actuator, and a butterfly valve. Air from the ship's start air system is supplied through an inlet fitting on the enclosure base to the starter

valve at 0 to 75 psig. When 28 volt d.c. power is supplied to the solenoid from the FSEE, the valve opens. It regulates discharge air pressure (to the starter) at 35 to 41 psig at a flow rate of 0 to 3.5 lb/sec.

Regulation is accomplished by the balance between the pneumatic actuator and a torsion spring on the butterfly. When the 28 volt d.c. signal is removed, the butterfly is closed by the pneumatic actuator and the torsion spring. Valve position is displayed by a mechanical position indicator at the valve. The valve position switch provides a valve position signal to the propulsion console.

LM2500 MODULE

The base/enclosure assembly has an enclosure on a shock-mounted base. It is about 26 feet long, 8 feet high, and 9 feet wide. The base/enclosure assembly is maintained in the installed position. That is, it is installed as a permanent part of the ship. This is opposed to the GT assembly which can be removed for major repair, overhaul, or replacement. Access for routine maintenance is provided by two entrances. Removable side panels are provided adjacent to one of the doors.

BASE

The base has a fabricated steel frame. It contains suitable mounts and links to secure the GT. Thirty-two shock mounts under the base secure the entire base/enclosure assembly to the ship's foundation. The shock mounts have two stacks of spring washers aligned above and attached to a resilient neoprene shock mount. They weaken shock loads by absorbing most of the abrupt up and down movements of the ship's foundation. The base also provides fittings for connection of electrical, air, CO_2, and liquid services (figure 5-42).

ENCLOSURE

The enclosure provides thermal and acoustical insulation. It also provides inlet and exhaust ducting, and a controlled environment for the GT. Flexible couplings are provided at the air inlet and exhaust ducts. This allows a flow path/interface between the enclosure and the ship's ducting. The right and left propulsion GT modules are functionally identical. They differ physically on the DD-963, DDG-993, and CG-47 classes only in the layout of the base/enclosure assemblies. The difference relates to access into the enclosure. Basically, entry to the left enclosure is through an access door on the left side of the enclosure. There is also an access hatch on the right side of the top panel. Entry to the right enclosure is through an access door on the right panel of the enclosure. The access hatch is on the left side of the top panel.

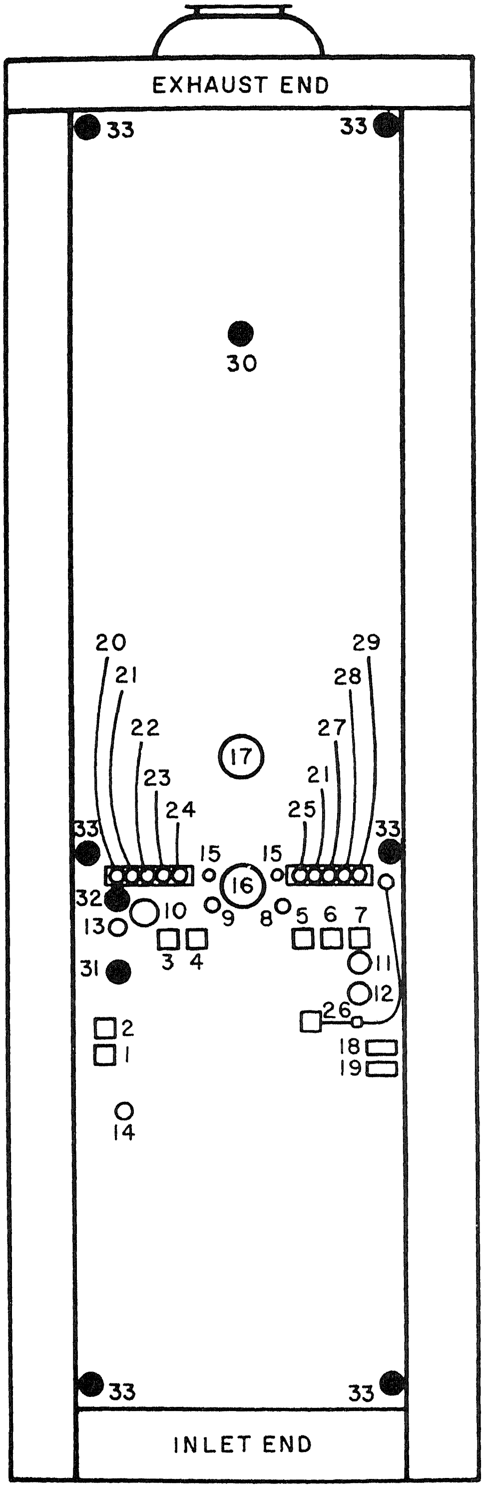
FIRE CONTAINMENT SYSTEM

All LM2500 modules have some method for detecting and extinguishing a fire in the enclosure. The sensors used to detect a fire are identical on all classes. These sensors are described in detail in chapter 3. The use of these sensors and the fire extinguishing systems varies with ship classes.

Fire Detection, Alarm, and Extinguishing—DD-963, DDG-993, and CG-47

The fire detection system has three flame detectors, a flame detector signal conditioner, and two temperature switches. The alarm system has a manual fire alarm pushbutton besides the electrical signal generated by either the temperature switch or the flame detector signal conditioner. The extinguishing system has two carbon dioxide (CO_2) discharge nozzles. It also has an extinguish release inhibit switch and a CO_2 release switch.

The UV flame detectors sense the presence of fire in the enclosure. They generate an electrical signal which is transmitted to the signal conditioner. The conditioner provides a signal to the ship's fire extinguishing system. The temperature switches are mounted on the interior ceiling of the enclosure. Temperature above a preset value causes switch contacts to close. This provides a signal to the ship's fire extinguishing system.



1. P_{T2} TRANSDUCER
2. P_{S3} TRANSDUCER
3. FUEL MANIFOLD PRESSURE TRANSDUCER
4. FUEL PUMP FILTER ΔP TRANSDUCER
5. LUBE OIL SUPPLY FILTER ΔP TRANSDUCER
6. LUBE OIL SUPPLY PRESSURE TRANSDUCER
7. $P_{T5.4}$ TRANSDUCER
8. E8-ICE DETECTOR AND FLAME DETECTOR SIGNAL CONDITIONER
9. E10-PRESSURE TRANSDUCERS (P_{S3}, P_{T2}, FUEL MANIFOLD PRESSURE, FUEL FILTER ΔP, LUBE SUPPLY FILTER ΔP, LUBE OIL, $P_{T5.4}$)
10. FUEL OIL INLET
11. LUBE OIL INLET
12. LUBE OIL SCAVENGE OUTLET
13. VENT DAMPER ACTUATOR AIR INLET
14. WATER WASH INLET
15. CO_2 INLETS (PRIMARY & SECONDARY)
16. STARTER AIR INLET
17. BLEED AIR OUTLET
18. FLAME DETECTOR SIGNAL CONDITIONER
19. ICE DETECTOR SIGNAL CONDITIONER
20. E11-PLA ACTUATOR MOTOR, RATE TACH, POSITION POT
21. BLANK
22. E6-VALVE CONTROLS (VENT DAMPER, STARTER REGULATOR SHUT-OFF, BLEED AIR, FUEL PURGE) AND, VENT DAMPER OPEN/CLOSE LIMIT SWITCH
23. E5-FUEL/ENCLOSURE HEATER POWER
24. E7-IGNITION, ENCLOSURE LIGHTS
25. E9-RTDS (T_2, FUEL INLET, COOLING AIR OUT)
26. E4-$T_{5.4}$ SIGNAL CONDITIONER
27. E3-POWER TURBINE SPEED PICKUPS NO.1 AND NO.2
28. E2-VIB TRANSDUCERS (GAS GENERATOR, POWER TURBINE) AND RTD'S (A, B, C, D SUMPS AND ACCESSORY G/B SCAVENGE OIL TEMPERATURE)
29. E1-FUEL S/D VALVES NO.1 AND NO.2 AND STARTER O/S SWITCH, GG SPEED PICKUP
30. EXHAUST DUCT DRAIN
31. FUEL SYSTEM DRAIN
32. FUEL MANIFOLD SHROUD DRAIN
33. MODULE FLOOR DRAINS

NOTE: PREFIX E DENOTES ELECTRICAL CONNECTOR

291.22

Figure 5-42.—Base penetration plate connections (bottom view).

The CO_2 release switch (figure 5-43) is mounted to the outside of the enclosure, next to the side access door. When manually activated, the CO_2 fire extinguishing agent is discharged into the enclosure.

The CO_2 discharge nozzles are located inside the enclosure. They are mounted on the crossbeam under the compressor front frame. There are two nozzles, one for initial discharge and one for extended discharge. The fire extinguish release inhibit switch is mounted above the fire alarm pushbutton. When in the INACTIVE position, this switch prevents discharge of the CO_2 extinguishing agent.

Fire is sensed by the flame detectors or temperature switches (figure 5-44). It may also be noted by a crew member who operates the manual CO_2 release switch. When this occurs, contacts

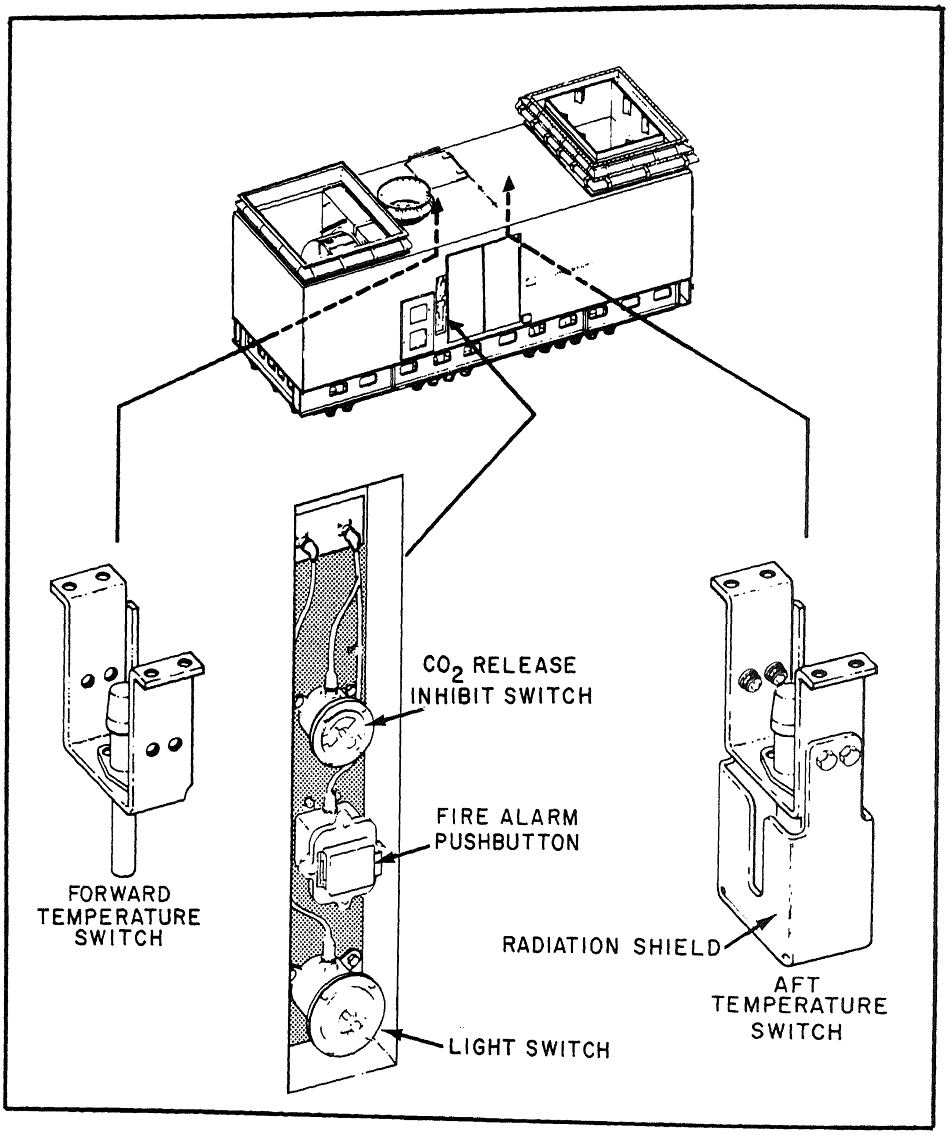


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Figure 5-43.—Fire system temperature sensors and manual switches.

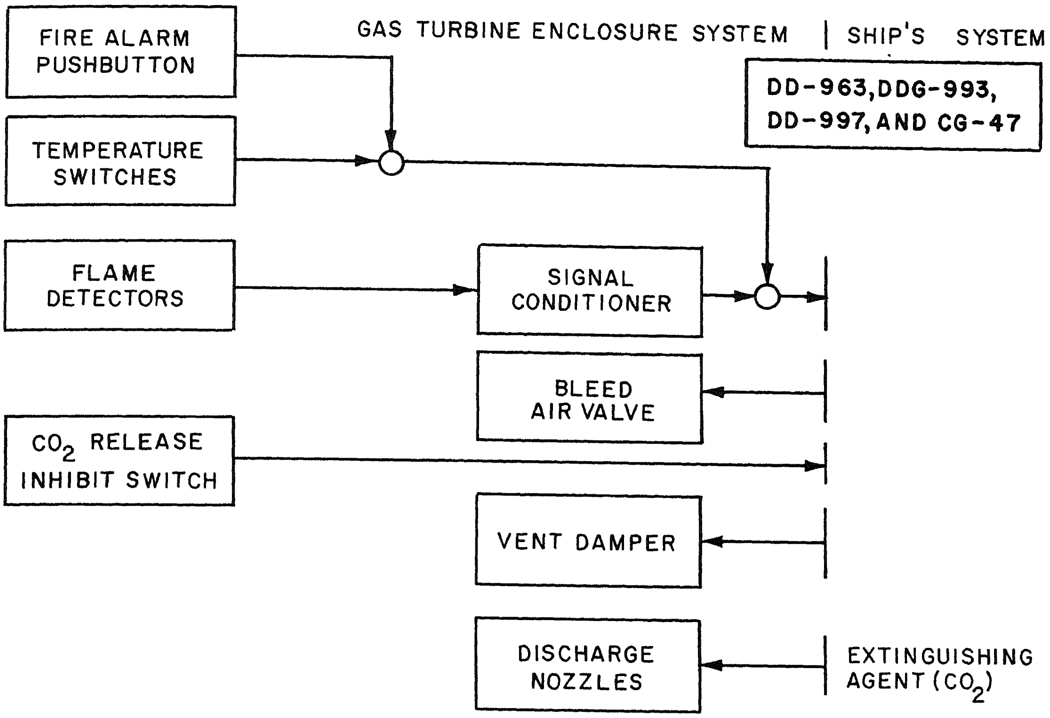

Figure 5-44.—Fire system block diagram.

close to activate the fire extinguishing system. The following concurrent actions occur:

1. The GT fuel shutdown valves close, shutting down the GT.
2. The fuel supply to the GTM is shut off in the ship's service system.
3. The bleed air valve is closed.
4. The secondary cooling air fan is shut down.
5. The secondary air vent damper is closed.
6. The fire alarm signal sounds.
7. The enclosure lights flash.
8. After a delay of 20 seconds, the initial CO_2 discharge occurs. You can prevent CO_2 discharge by positioning the release inhibit switch to the INACTIVE position during the time delay. The initial discharge delivers 150 pounds of CO_2 at a rate of 50 lb/min. If required, the extended CO_2 discharge is manually activated. The extended discharge delivers 200 pounds of CO_2 at the rate of 10 lb/min.

Fire Detection, Alarm, and Extinguishing—FFG-7

Like the other ship classes discussed above, the fire detection system of the FFG-7 class has three flame detectors, a flame detector signal conditioner, and two temperature switches. The alarm system consists of a fire alarm pushbutton. The extinguishing system consists of a single Halon discharge nozzle, connecting tubing, and an extinguish release inhibit switch.

The UV flame detectors of the FFG-7 class are identical to the type on the DD-963, but provide only an alarm. The RTD fire sensor will also sound that same alarm indicating a fire is present.

The fire alarm pushbutton is mounted on the outside of the enclosure, next to the side access door. When manually activated, contact closure signal is provided to the ship's system which sounds an alarm.

The Halon discharge nozzle is located inside the enclosure. It is mounted on the underside of the crossbeam under the compressor front frame.

This one nozzle provides both initial and standby Halon discharge. The fire extinguish inhibit switch is mounted above the fire alarm pushbutton. When in the INACTIVE position, this switch provides a signal to the ship's system. This is used to prevent discharge of the fire extinguishing agent.

Fire may be sensed by the flame detectors (figure 5-45) or the temperature switches detect enclosure temperature above preset limits. It also may be detected by the manual fire alarm pushbutton. If it is activated, an alarm sounds. Panel indicator lights also inform the ship's operator of the condition.

A fire in either enclosure is extinguished by filling the enclosure with Halon. The ship's PCC has a Halon FLOOD pushbutton for each enclosure. To prevent an enclosure from being flooded with Halon while personnel are inside, use the safety disable switch (fire extinguish inhibit). This is located next to the enclosure access door and is positioned to INACTIVE.

Activation of the FLAME DET ALARM/HALON FLOOD switch on the PCC will provide the initial Halon discharge of 20 pounds at a rate of 1.45 lb/sec. An additional 20 pounds, with the same rate of discharge, is available on standby.

SUMMARY

In this chapter we have described the construction of the LM2500. You have learned about the engine description as well as the components that support the engine operation. This information is provided to give you, the GSE, an understanding of where these components are located. It also will help you understand the operation of the engine which we will discuss in the next chapter. This chapter has been thorough in describing the engine. However, you should always refer to the manufacturers' technical manuals before performing any maintenance on the LM2500.

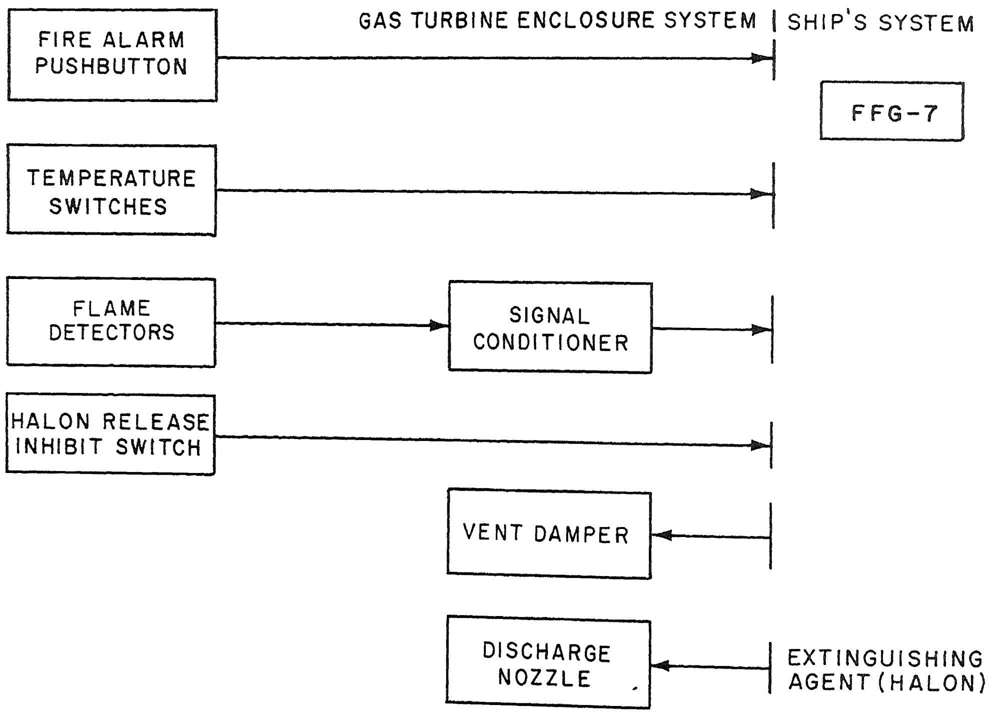

Figure 5-45.—Fire system block diagram, FFG-7.

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CHAPTER 6

LM2500 GAS TURBINE ENGINE OPERATION

To recognize problems with the LM2500, you must first understand its operation. In chapter 5 we discussed the construction of the LM2500. In this chapter we will discuss the operation of the engine from the local operating stations. We will cover the modes of operation, the control stations, and basic engine procedures and parameters related to the control stations. The operational limits and engine operating procedures are similar on all gas turbine powered ships. The control systems on the different classes do vary, though, causing some differences in modes of control and types of automatic operations. For this reason we will separately discuss each control console and its operations.

After reading this chapter and completing the associated assignments, you should understand the differences in engine control stations. You should also be able to identify the operating procedures and parameters of each engine control station. Also, you should have a basic understanding of the procedures for normal and emergency operation of the LM2500.

Keep in mind that the operations described in this chapter are presented to form a basis for your understanding the LM2500 operation. When actually operating any engineering equipment, you must always follow the EOSS. The EOSS is a step-by-step procedure. Its use is mandated by fleet commanders. Failure to use this very important document can cause casualties to very expensive and vital ship's equipment. Even the most experienced engineer uses the EOSS to start or stop equipment.

OPERATING STATIONS

Operation of main propulsion gas turbines is done from several different locations. The major classes of Navy ships that use the LM2500 engine have three control points. The first control station is in the engine room. This is known as the local operating panel (LOP) on the FFG-7 class. It is known as the propulsion local control console (PLCC) on all twin shaft gas turbine ships such as the DD-963 class. The engine-room control consoles are the *primary control consoles.* This is not to say that the engine-room console is in control most of the time. What is meant by primary is it may take control from any other remote station. For example, a ship is being operated with the throttle control at the pilothouse. However, the engine-room operator places the throttle control to local. Automatically, the engine room assumes control of the throttle operation.

The next level of control is in the central control station (CCS). This will be discussed in depth in later chapters. CCS is normally the control station for starting, stopping, and monitoring the LM2500. On the FFG-7 class ships this station is known as the propulsion control console (PCC). On the twin shaft ships the main engine control is known as the propulsion and auxiliary control console (PACC).

The third level of control is on the bridge. This station, known as the ship control console (SCC), may have direct throttle control of the engineering plant. (This control is done in the integrated or programmed control.) It allows the officer of the deck (OOD) to have direct throttle and pitch control. This eliminates the need for an engine order to be passed to central control and allows quicker maneuvering of the ship.

In the next section we will discuss the different local consoles used for LM2500 operation. Remember to refer to the EOSS any time you are operating at any of these stations.

ENGINE-ROOM CONTROL CONSOLES

As we discussed earlier, the engine-room console is the primary operating station for the LM2500. The primary purpose of the engine-room consoles is to allow you to operate an engine room independent of all other control points. If the SCC or CCS is damaged, you could still control the engines from the engine room. These consoles are also used as maintenance stations for operations such as water washing and as a central monitor for many engine-room parameters.

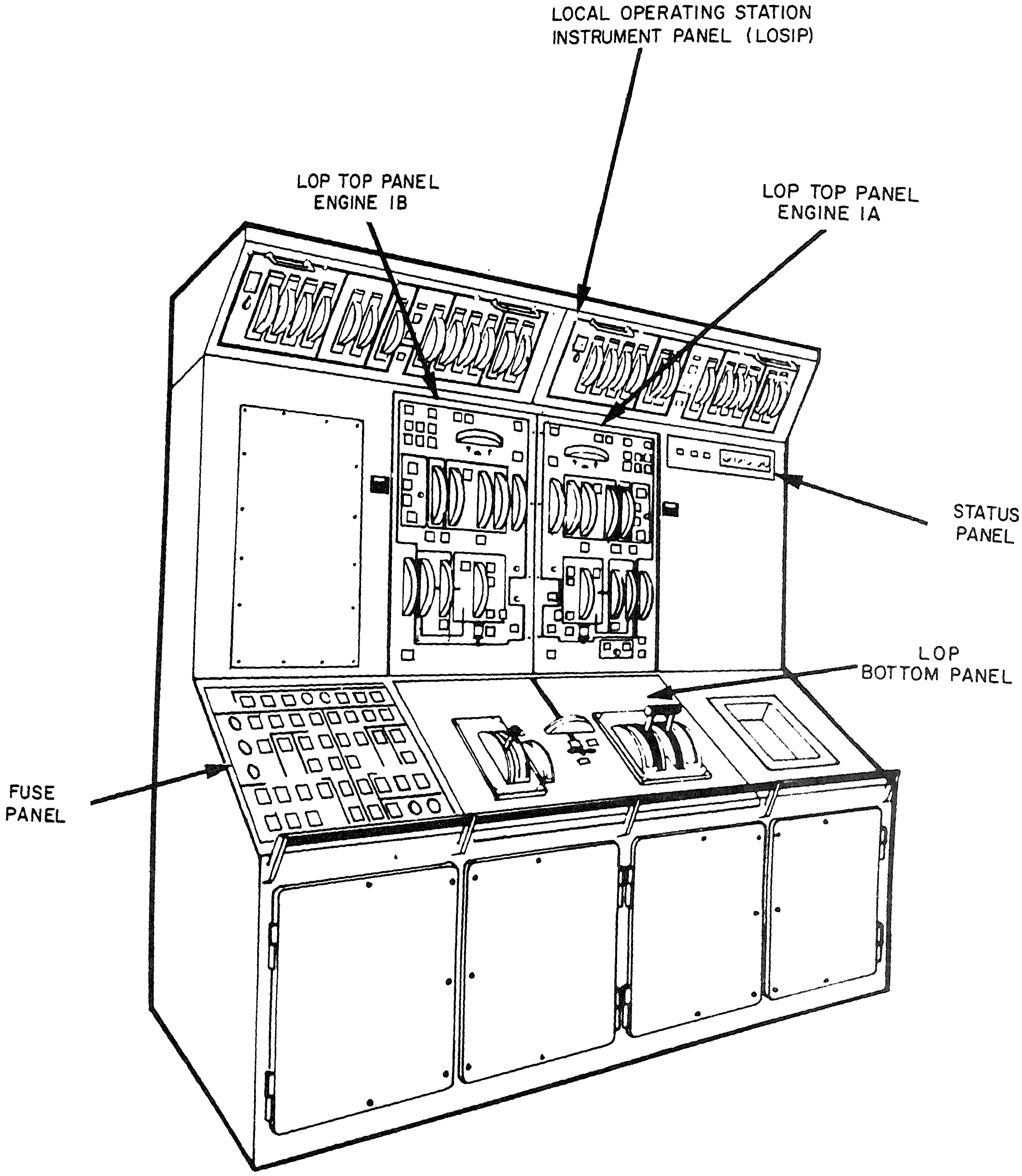

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Figure 6-1.—FFG-7 LOP controls and displays.

LOCAL OPERATING PANEL

The LOP (figure 6-1) is the engine-room console on the FFG-7 class ship. It is located in the engine room near the propulsion equipment. The LOP has the necessary controls and indicators to permit direct local (manual) control of the propulsion equipment. The direct local mode of control, although still electronic, permits operation of the equipment independent of the programmed sequence from the computer. It is normally an unmanned console. However, you can use it in the event of an emergency or for control during maintenance. You may find it easier to understand the operational procedures for the LM2500 by following the operation of the programmed sequence. For this reason, we will discuss FFG-7 LM2500 operational procedures in more detail when discussing the PCC in chapter 10.

The LOP is divided into the following six sections.

1. Local operating station instrument panel (LOSIP)
2. LOP top panel engine 1A
3. LOP top panel engine 1B
4. Status panel
5. LOP bottom panel
6. Fuse panel

Local Operating Station Instrument Panel

The LOSIP (figure 6-2) is located at the top of the LOP. The LOSIP is divided into two sections, one for each engine. Their layouts are identical. The LOSIP has no control functions. It is only a monitoring panel. It is used to monitor conditions of the systems of the LM2500 and selected engine parameters.

As shown on figure 6-2, from left to right the sections monitored are lube oil (section A), fuel (section B), throttle (section C), enclosure (section D), GG (section E), and PT (section F). Please follow figure 6-2 as we discuss the six sections of the LOSIP. The parenthetical letters are indicated on figure 6-2.

LUBE OIL MONITORING.—The lube oil section (A) is used to monitor the parameters associated with the LM2500 lube oil system. The selector switch on the left is a five-position switch used to select the scavenge temperature (temp) to be monitored. It is used in conjunction with the scavenge temp meter located next to it. You can select either the A through D sumps or the gearbox scavenge oil temp by moving the selector switch. The second meter is used to monitor the scavenge filter (located on the LOSCA) differential pressure. The third meter indicates the LOSCA tank level. The last lube oil meter is used to indicate differential pressure across the lube oil supply filter (located in the module).

FUEL SYSTEM MONITORING.—The fuel section (B) monitors the fuel system of the engine. It has two meters to monitor fuel filter differential pressure (the engine-mounted filter) and fuel inlet temperature.

THROTTLE MONITORING.—The throttle meter section (C) indicates the percentage of engine power. It is in increments of 0 to 100 percent.

ENCLOSURE MONITORING.—The enclosure section (D) has two indicators. One is for the status of the vent damper OPEN/CLOSED. The other indicator is for the UV sensors in the enclosures. This indicator reads FLAME, indicating that a flame has been sensed in the module. There is also a meter in this section for the temperature of the enclosure. A lamp test button is located below the two indicators. This is used to test the bulbs in the two indicators.

GAS GENERATOR MONITORING.—The next section (E) is used to monitor the GG. It has three meters. The first one monitors inlet air pressure (P_{t2}), the pressure of the air entering the compressor. The center meter monitors the compressor air inlet temperature (T_2). The right meter monitors the compressor air discharge pressure (CDP).

POWER TURBINE MONITORING.—Two meters are used to monitor PT parameters (F). The left-hand meter is used to measure PT inlet pressure ($P_{t5.4}$). The second meter is used to monitor GG pressure ratio.

LOP Top Panel

The LOP top panel is divided into two sections, the engine 1A and engine 1B sections. Refer to figure 6-3 as we discuss the LOP top panel of

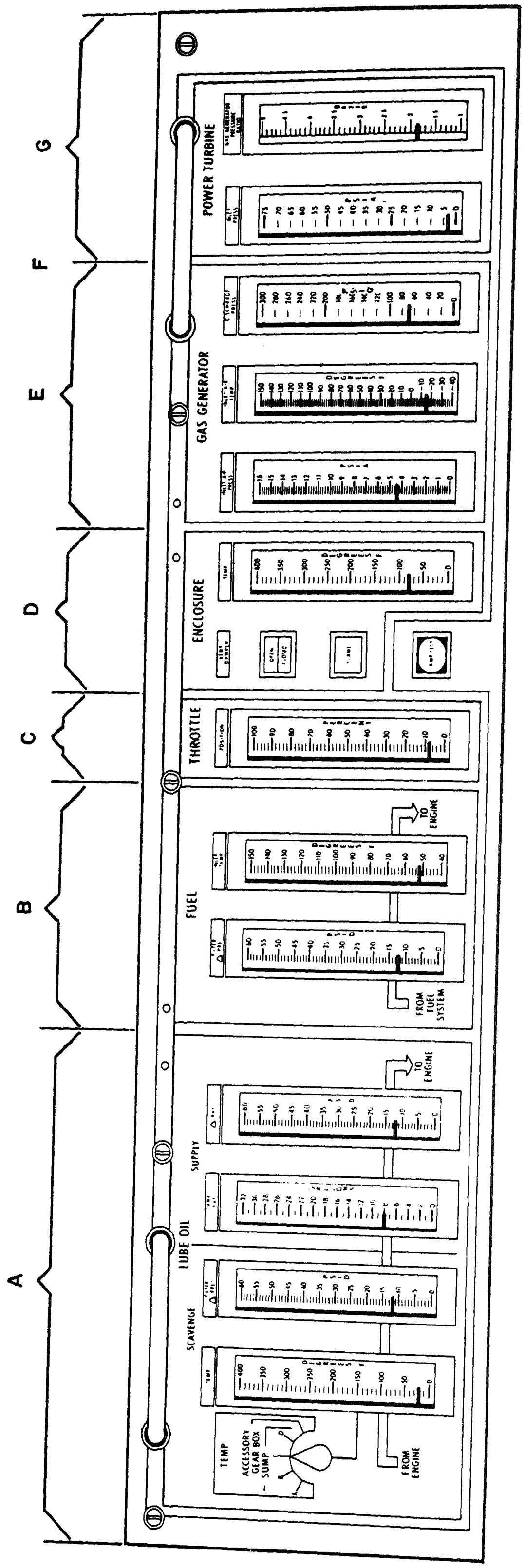

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Figure 6-2.—FFG-7 local operating station instrumentation panel.

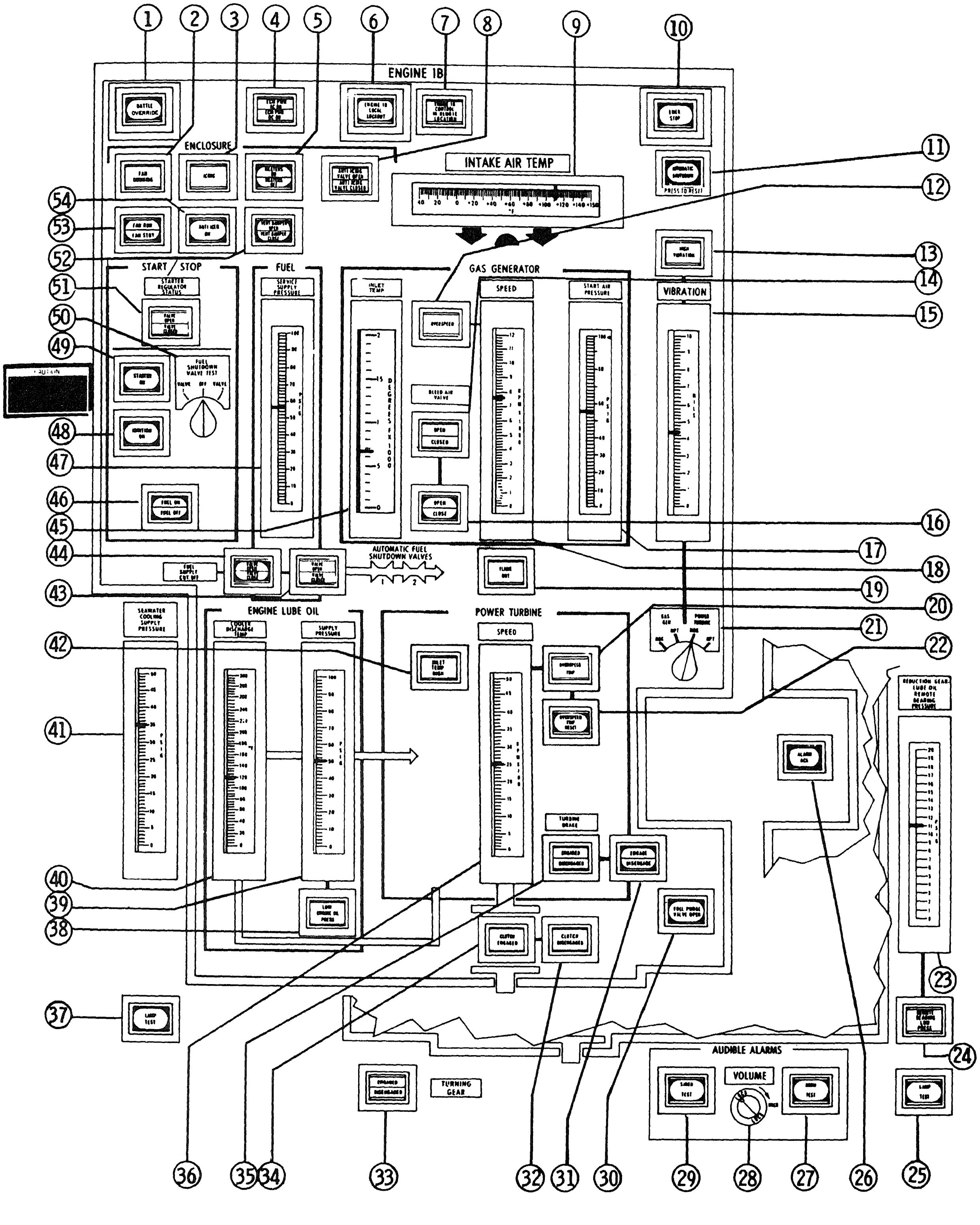

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Figure 6-3.—LOP top panel.

engine 1B. The parenthetical numbers are indicated on figure 6-3.

The LOP top panel is used to control either of the GTMs. Although the engines are controlled from this panel, the operations are in the manual mode. There are no computer functions at the LOP.

BATTLE OVERRIDE.—BATTLE OVERRIDE (1) is a guarded, illuminated pushbutton. You can use it at any time, regardless of the station in control. This switch overrides the following shutdowns.

1. GTM low lube oil pressure
2. High engine vibration
3. High $T_{5.4}$
4. Power lever angle failure for:

   a. PCS command signal out of limits
   b. PT shaft torque out of limits
   c. PT speed out of limits

It does not override a flameout or a PT overspeed trip.

ENCLOSURE SECTION.—The enclosure section monitors the module cooling and air intake system. A description of the function of each indicator in this section follows.

FAN RUNNING (2) indicates the enclosure fan is operating when illuminated.

FAN RUN/FAN STBY (53) turns the cooling fan on or returns it to a standby condition (off).

ICING (3) indicates the intake air is below 41 °F and the humidity is above 70 percent.

ANTI-ICER ON (54) illuminates to indicate a command has been sent to open the anti-icing valve. Depressing this button again will close the anti-icing valve.

HEATERS ON/HEATERS OFF (5) turns the enclosure heater on or off.

VENT DAMPER OPEN/VENT DAMPER CLOSE (52) opens or closes the vent damper.

ANTI-ICING VALVE OPEN/ANTI-ICING VALVE CLOSED (8) shows the status of the anti-icing valve.

ECM POWER INDICATOR.—The ECM PWR AC ON/ECM PWR DC ON indicator (4) is a split legend type. The upper half indicates a.c. power is on to the FSEE. This a.c. power is used for igniters, anti-icing, and fire detection. The lower half indicates d.c. power is on. This d.c. power is used for the FSEE electronics and the engine fuel valve control circuit.

ENGINE CONTROL PUSHBUTTON OR INDICATOR.—The ENGINE 1B LOCAL LOCKOUT pushbutton (6) places the LOP in control of the associated engine. This is used to take control from the PCC. It is a guarded type of pushbutton. By redepressing it, you can have the control of the engine transferred to the PCC. When the engine control is at the PCC, the ENGINE 1B CONTROL IN REMOTE LOCATION indicator (7) will illuminate.

EMERGENCY STOP PUSHBUTTON.—The EMER STOP pushbutton (10) is used to stop the engine in an emergency. It is a guarded type of pushbutton. You can activate the emergency stop pushbutton, regardless of what station has control. This pushbutton closes both engine fuel valves and causes the engine to shut down.

AUTOMATIC SHUTDOWN INDICATOR/PUSHBUTTON.—The AUTOMATIC SHUTDOWN indicator (11) indicates an emergency shutdown has occurred on the related engine. The automatic shutdowns are as follows:

1. PT inlet temp high ($T_{5.4}$) above 1530 °F
2. Engine lube oil pressure low below 6 psig
3. High GG vibration above 7 mils
4. High PT vibration above 10 mils
5. Flameout: $T_{5.4}$ less than 400 °F with fuel manifold pressure above 50 psig

When one of the above conditions is met, the automatic shutdown circuitry closes the two main fuel valves. You can push this pushbutton to reset the automatic shutdown circuitry, once the engine has come to a complete stop.

VIBRATION SECTION.—This portion has a meter, switch, and an indicator.

The VIBRATION meter (15) is always reading the vibration on the engine at the position selected by the switch.

The GAS GEN/POWER TURBINE switch (21) is a four-position switch. It allows you to look at the two different vibration pickups. One is located on the GG and the other is on the PT. Each pickup senses both GG and PT vibration. A tracking filter for each pickup separates GG vibration from PT vibration depending on vibration frequency. Limits apply to frequency and not pickup location.

The HIGH VIBRATION indicator (13) will illuminate when the vibration on the GG reaches 4 mils, and the PT reaches 7 mils. An automatic shutdown occurs when GG vibration reaches 7 mils, and PT vibration reaches 10 mils.

GAS GENERATOR SECTION.—This section monitors parameters associated with the GG. It contains four meters, two indicators, and an illuminated pushbutton.

INTAKE AIR TEMP meter (9) monitors the temperature of the outside air. This meter is located above the intake air section.

START AIR PRESSURE meter (17) measures the pressure of the air used to start the engine.

The GG SPEED meter (18) monitors N_{GG}. The readings from this meter are multiplied by 1000 to determine GG speed. The OVERSPEED indicator (12) will illuminate when the speed of the GG exceeds 9700 ± 100 rpm.

The BLEED AIR VALVE indicator (14) displays the OPEN or CLOSED status of the engine's 16th-stage bleed air valve. A split indicator is used to display either the OPEN or CLOSED position. The bleed air OPEN/CLOSE pushbutton (16) controls the operation of the engine bleed air valve. It will illuminate either open or close depending on the command that is selected. The INLET TEMP meter (45) displays the $T_{5.4}$ of the PT. You have to multiply the number displayed by 1000 to determine the actual temperature.

FUEL SECTION.—The fuel section contains a meter, an indicator, and a pushbutton associated with the GTM fuel supply. The SERVICE SUPPLY PRESSURE meter (47) displays the fuel supply pressure from the ship's fuel system. The VALVE OPEN/VALVE CLOSE pushbutton (44) and VALVE OPEN/VALVE CLOSED indicator (43) control and display the status of the module fuel cutoff valve located under the enclosure.

START/STOP SECTION.—The start/stop section contains the controls to start and stop the GTM. The STARTER REGULATOR STATUS indicator (51) is a split indicator. It displays the open or closed status of the starter regulator valve. The STARTER ON pushbutton (49) is a momentary switch. It opens the starter regulator valve when depressed and closes it when released.

The IGNITION ON pushbutton (48) is also a momentary-type switch. When depressed, it turns the engine ignitors on; when released, the ignitors are turned off.

The FUEL ON/FUEL OFF pushbutton (46) is used to energize or de-energize the fuel shutdown valves. By depressing it once, you can open the fuel valves. Redepressing it closes the valves. You must always keep the pushbutton in the FUEL OFF position when control is at the PCC.

The FUEL SHUTDOWN VALVE TEST switch (50) is used to test each fuel valve. The switch is spring loaded to the OFF position. To test an individual valve, you must turn the switch to the desired valve and hold it. You must keep the switch held to that position until the N_{GG} is at zero. Then depress the FUEL ON/FUEL OFF pushbutton (46) to close the other valve and keep both valves closed.

SEAWATER COOLING METER.—The SEAWATER COOLING SUPPLY PRESSURE meter (41) is used to display the reduction gear cooler seawater supply pressure.

A LAMP TEST pushbutton (37) is located below the seawater cooling meter. It is used to test the lamps in this section of the LOP.

REDUCTION GEAR LUBE OIL REMOTE BEARING PRESSURE METER.—Figure 6-3 shows the LEFT LOP top panel. On the right panel a REDUCTION GEAR LUBE OIL REMOTE BEARING PRESSURE meter (23) displays the most remote bearing pressure. Below this is the REMOTE BEARING LOW PRESS indicator (24) which alerts the operator if the most remote bearing falls below 9 psig.

ENGINE LUBE OIL SECTION.—The engine lube oil section has two meters and an indicator to monitor the engine lube oil supply. The COOLER DISCHARGE TEMP meter (40) monitors the temperature of the LOSCA cooler outlet. The SUPPLY PRESSURE meter (39) monitors the engine lube oil supply pressure. The LOW ENGINE OIL PRESS indicator (38) located below this meter illuminates when the engine lube oil pressure is below 15 psig.

COMBUSTOR, POWER TURBINE, AND OUTPUT.—The FLAME OUT indicator (19) alerts you if conditions for a flameout exist. The condition occurs if the $T_{5.4}$ drops below 400 °F when the fuel manifold pressure is above 50 psig. This also initiates an automatic shutdown.

The PT INLET TEMP HIGH indicator (42) illuminates to alert the operator of a high $T_{5.4}$. This will occur at 1500 °F PT inlet temp.

The PT SPEED meter (36) is used to monitor the speed of the PT. Associated with this meter is an indicator and pushbutton. The PT OVERSPEED TRIP indicator (20) illuminates when an overspeed trip occurs. The indicator is set at 3960 ± 40 rpm. The OVERSPEED TRIP RESET pushbutton (22) resets the overspeed trip circuitry. Use this after an overspeed trip occurs. NOTE: Do not reset until the gas generator has come to a complete stop. If you do not, a post-shutdown fire may occur.

The TURBINE BRAKE section has a pushbutton (31) that controls the operation of the PT brake. It is a split indicator type of pushbutton. The indication illuminates the signal that is being sent to the turbine brake control, either ENGAGE or DISENGAGE. The TURBINE BRAKE indicator (35) is also a split-type indicator. It displays the actual position of the turbine brake, either ENGAGED or DISENGAGED.

The two clutch indication lights display the status of the GTM clutch. These indicators (32 and 34) display either CLUTCH ENGAGED (34) or CLUTCH DISENGAGED (32) status.

A FUEL PURGE VALVE OPEN pushbutton (30) operates the engine's fuel purge valve. Depressing this button opens the fuel purge valve. About 3 gallons of fuel will be drained from the engine system. In this way cold fuel is drained from the GTM before starting. Operate fuel purge only when the engine is rotating.

TURNING GEAR INDICATOR.—The TURNING GEAR indicator (33) shows the status of the MRG turning gear. This is a split-type indicator and displays either ENGAGED or DISENGAGED. It is located below the A engine section.

AUDIBLE ALARMS SECTION.—The AUDIBLE ALARMS section has the controls to adjust the alarm volume and test the horn and siren. The alarm VOLUME rheostat (28) adjusts the alarm volume. The alarm test pushbuttons

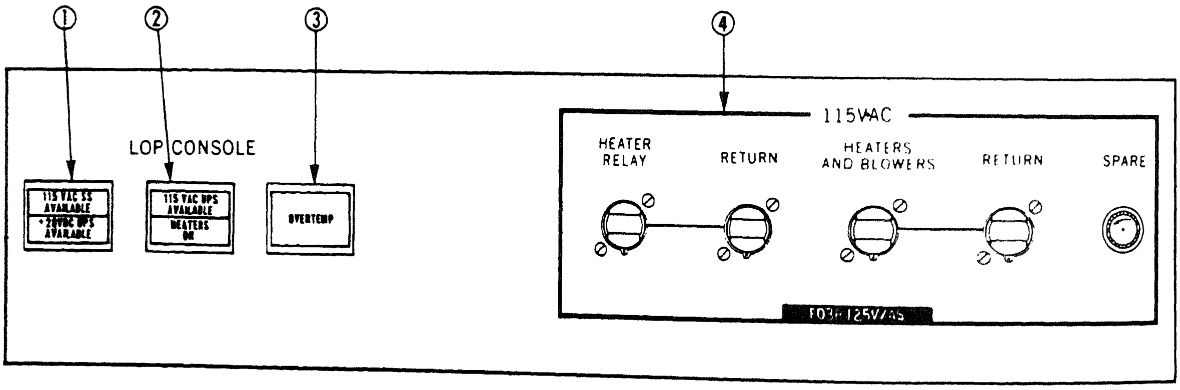

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Figure 6-4.—LOP status panel.

HORN TEST (27) and SIREN TEST (29), are depressed to test the horn and siren.

LOP Status Panel

The LOP status panel (figure 6-4) is located to the right of the A engine top panel. It contains the indicators for LOP power supplies and the 115 volt a.c. fuses for console heaters and blowers. The parenthetical numbers in the following paragraphs are indicated on figure 6-4.

The first indicator (1) is a split indicator. It displays the status of 115 volt a.c. ship's service power and 28 volt d.c. power. These indicators will illuminate when each source of power is available. The second indicator (2) is also a split type. It displays the status of the 115 volt a.c. uninterruptible power supply (UPS) and the heaters on status. The third indication (3) displays console overtemperature.

The 115 volt a.c. fuse section (4) contains the fuses for the heater relay and power for the heaters and blowers.

LOP Bottom Panel

The LOP bottom panel (figure 6-5) contains the shaft operating and monitoring controls and indicators. Only manual throttle and pitch control is available at the LOP. The parenthetical numbers in the following paragraphs are indicated on figure 6-5.

The PITCH CONTROL (1) controls the pitch of the propeller. It is only operative when the LOP is in control of both engines. Associated with it is a PITCH indicator (2) which displays the actual propeller pitch. Above this meter is an ASTERN PITCH indicator (3). This illuminates when pitch is actually in the astern direction. The PROP HYDRAULIC PRESS LOW indicator (4) will alert you when the CPP hydraulic pressure system is below 40 psig.

The SHAFT BRAKE indicator (5) and control (7) control and monitor the shaft brake. When you depress the shaft brake control button, it will illuminate the command selected. The shaft brake will only activate when the following permissives are met.

- Pitch at zero
- Shaft speed below 75 rpm
- Throttles at idle
- Station in control

The SHAFT BRAKE indicator (5) will display the actual status of the shaft brake, either ENGAGED or DISENGAGED.

The SHAFT SPEED meter (6) displays the speed of the shaft in rotations per minute (rpm).

The REMOTE THROTTLE CONTROL levers (8) control the power level of each GTM. The throttles are controlled in increments of percent power.

LOP Fuse Panel

The LOP fuse panel (figure 6-6) is located on the lower left section of the LOP. It contains the 28 volt d.c. fuses for the LOP, the enclosures, and the transducers that input the LOP.

PROPULSION LOCAL OPERATING EQUIPMENT

The propulsion local operating equipment (PLOE) is the engine-room control equipment on DD-963, DDG-993, and CG-47 class ships. Two identical PLOEs are on each ship, one in each engine room. PLOE number 1 is located in main engine room (MER) 2 while PLOE number 2 is in MER 1. Each PLOE has two units. The major component is the propulsion local control console (PLCC). The PLCC is the local operating station. The second unit is the propulsion local control electronic enclosure (PLCEE). This unit contains the power supplies for the PLCC. Other than on/off control, there are no operator functions at the PLCEE.

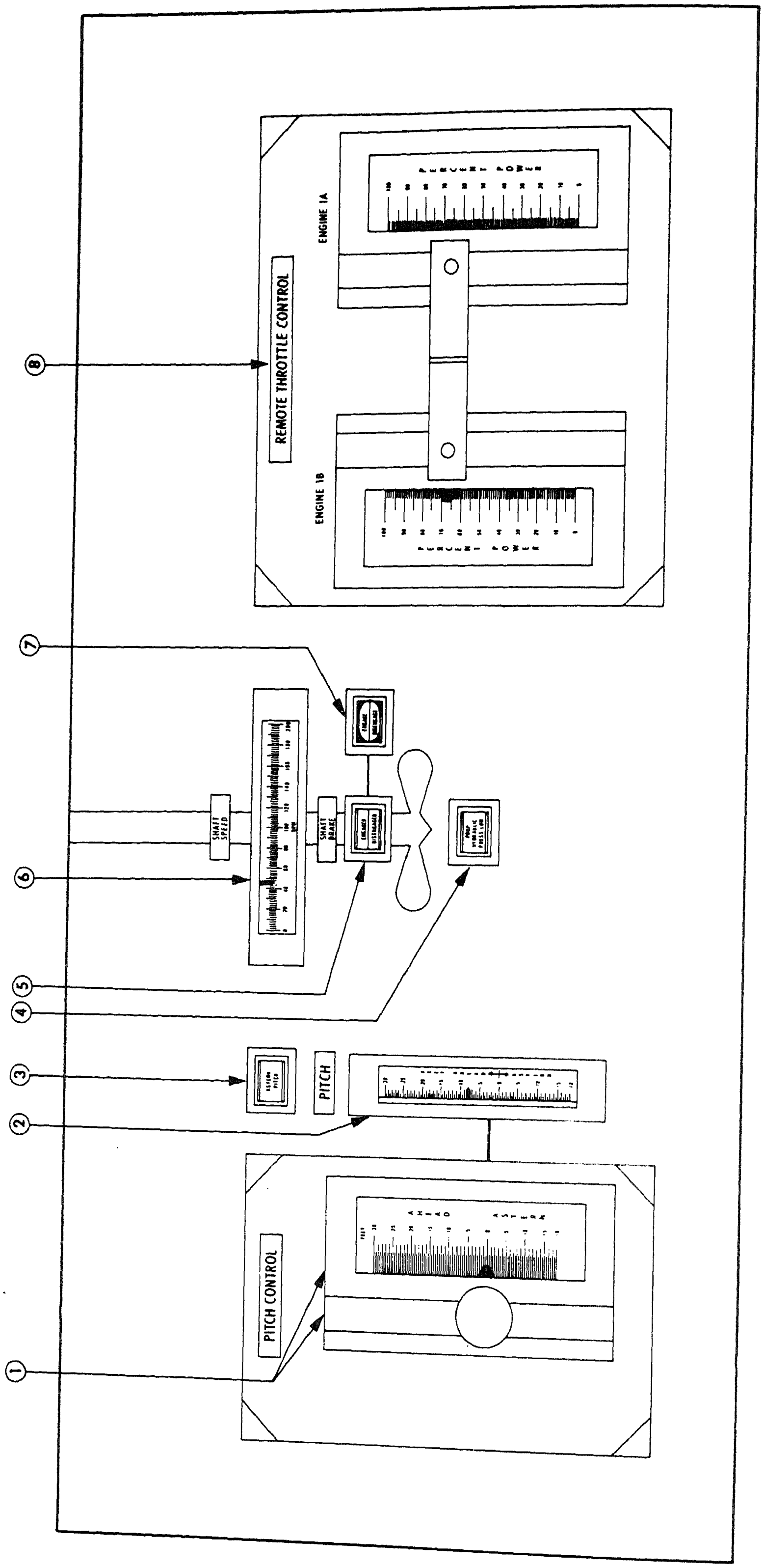

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Figure 6-5.—LOP bottom panel.

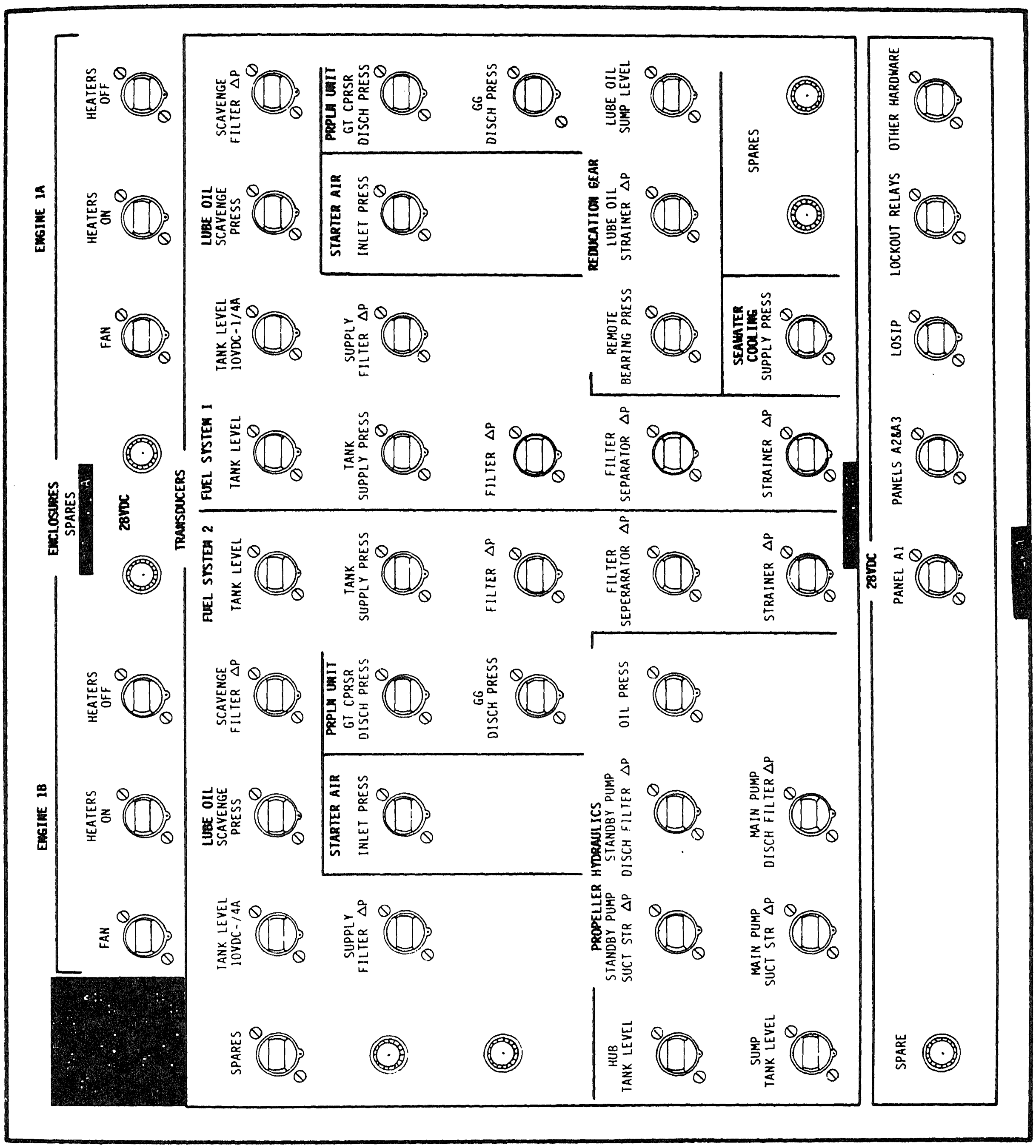

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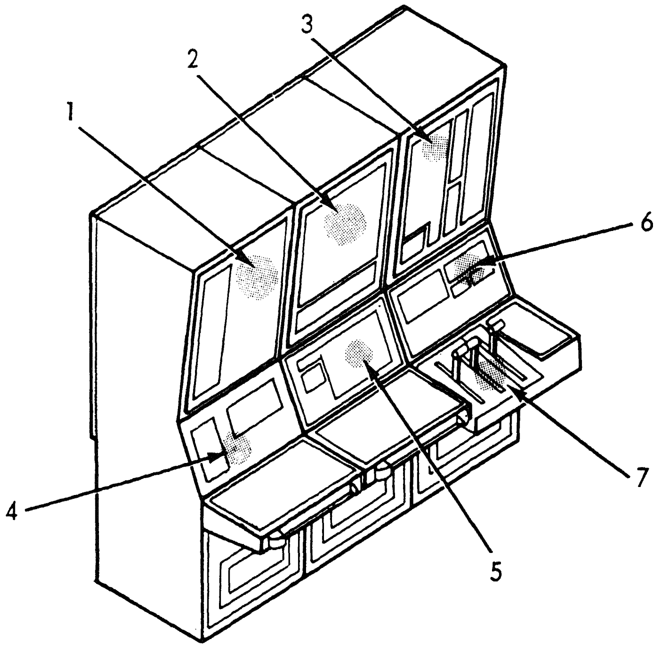
Figure 6-6.—LOP fuse panel.



1. FUEL OIL/GTM B PANEL
2. GTM A/B PANEL, BLEED VALVE CONTROLS
3. MAIN REDUCTION GEAR, CRPP, GTM A PANEL
4. SELF-TEST PANEL/GTM B START STOP MODE CONTROLS
5. EOT/ALARM ACKNOWLEDGE PANEL
6. ALARM TEST PANEL/ GTM A START STOP MODE CONTROLS
7. THROTTLE CONTROLS

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Figure 6-7.—Propulsion local control console—major sections.

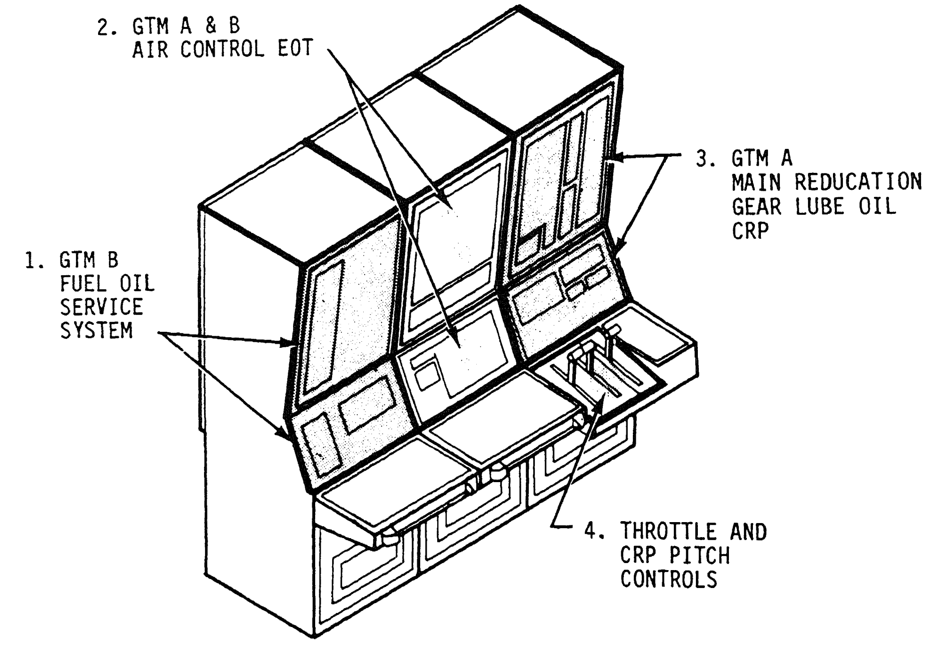

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Figure 6-9.—Propulsion local control console—panel arrangement.

Propulsion Local Control Console

The PLCC is divided into six panels. Figure 6-7 illustrates the console and the six panels. Figure 6-8 (foldout at the end of this chapter) is a more detailed view of the console's six panels.

Each PLCC has the principal electronics necessary for controlling and monitoring the propulsion plant within that engine room. The console is arranged in a logical layout into four major sections (figure 6-9). Please follow the illustrations of the console from left to right as we discuss the sections and their purposes.

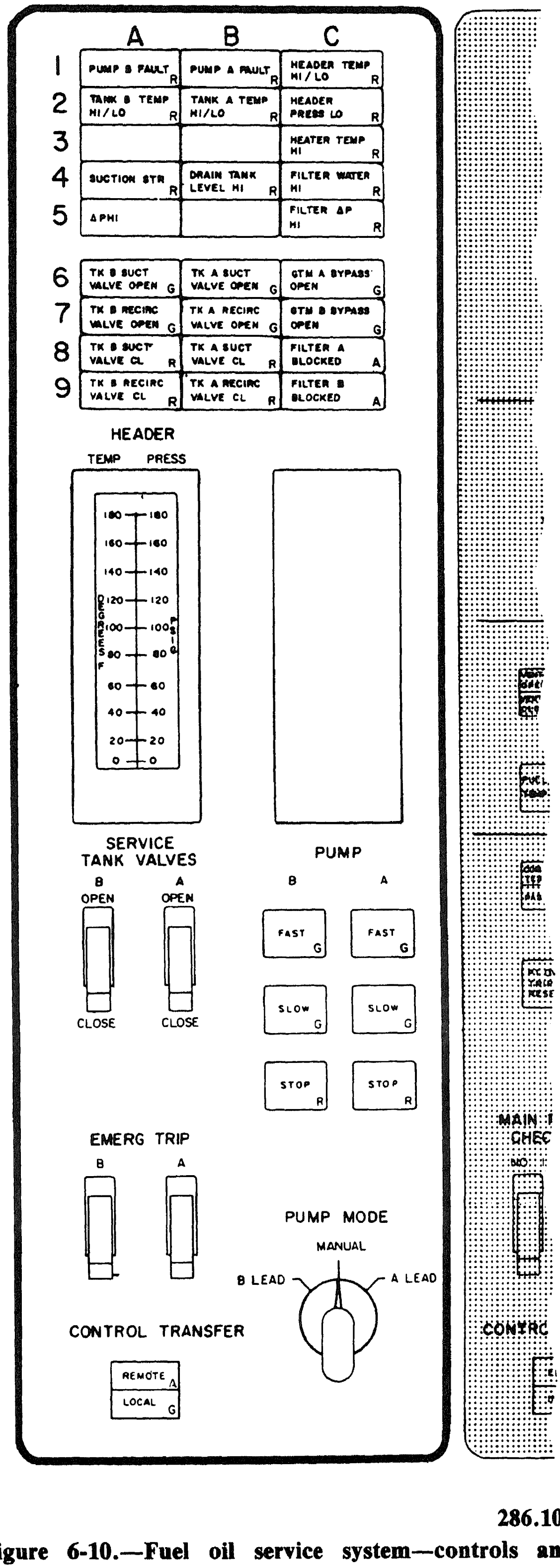
1. The GTM B and the FUEL OIL SERVICE SYSTEM section has the controls and status indicators for GTM B and the controls, status indicators, and alarm indicators for the FO service system.
2. The GTM A and B, AIR CONTROL, and ENGINE ORDER TELEGRAPH (EOT) section has the alarm indicators for GTMs A and B, the controls and alarm indicators for starter (bleed) air, and the EOT.
3. The GTM A, MAIN REDUCTION GEAR LUBE OIL, and CONTROLLABLE REVERSIBLE PITCH PROPELLER section has the controls and status indicators for GTM A; the controls, status indicators, and alarm indicators for the MRG lube oil system; and the controls, status, and alarm indicators for the controllable reversible pitch (CRP) propeller system.
4. The THROTTLE AND CRP PITCH CONTROLS section has the power level angle throttle controls and the propeller pitch control.

FUEL OIL SERVICE SYSTEM.—The FO subpanel (figure 6-10) is located on the upper left panel of the console. For easier description the indicator section is divided into columns with row numbers beside the A column. A description of the indicators and the parameters to activate them follows (the indicator colors are in parentheses).

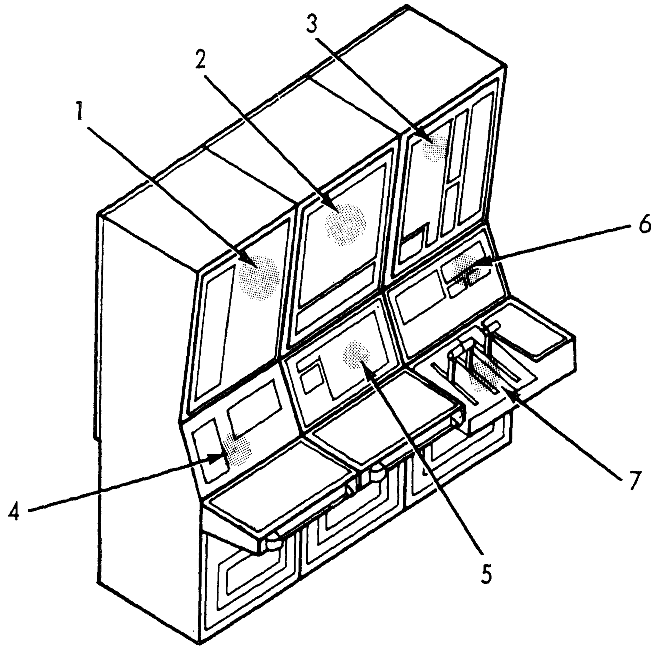
A-1. PUMP B FAULT (red). The pump must be running and the discharge pressure less than 35 psig for 9 seconds

A-2. TANK B TEMP HI/LO (red). HI 130 °F, LO 60 °F

A-3. Blank



286.103
Figure 6-10.—Fuel oil service system—controls and indicators.



1. FUEL OIL/GTM B PANEL
2. GTM A/B PANEL, BLEED VALVE CONTROLS
3. MAIN REDUCTION GEAR, CRPP, GTM A PANEL
4. SELF-TEST PANEL/GTM B START STOP MODE CONTROLS
5. EOT/ALARM ACKNOWLEDGE PANEL
6. ALARM TEST PANEL/ GTM A START STOP MODE CONTROLS
7. THROTTLE CONTROLS

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Figure 6-7.—Propulsion local control console—major sections.

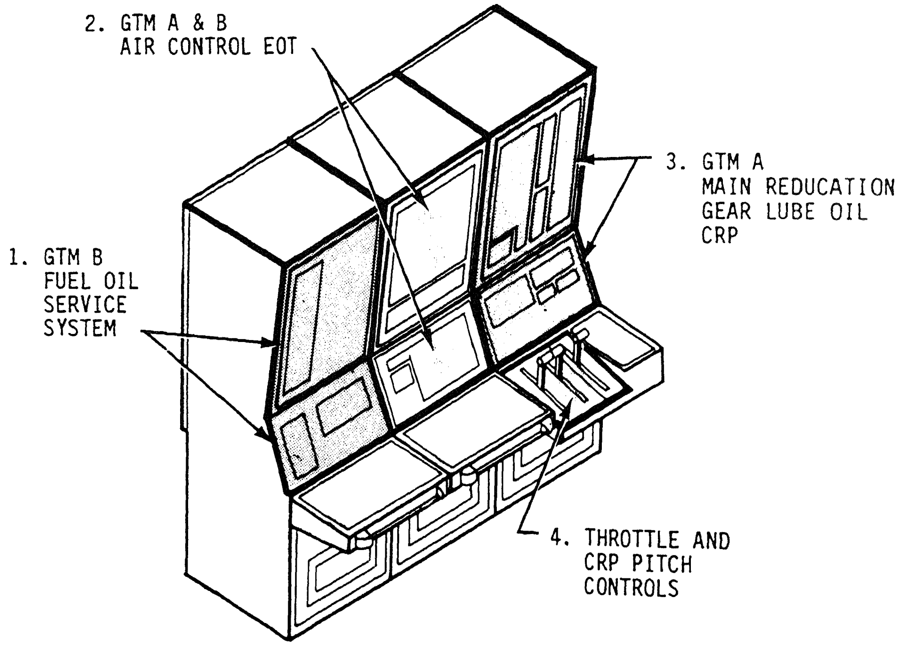

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Figure 6-9.—Propulsion local control console—panel arrangement.

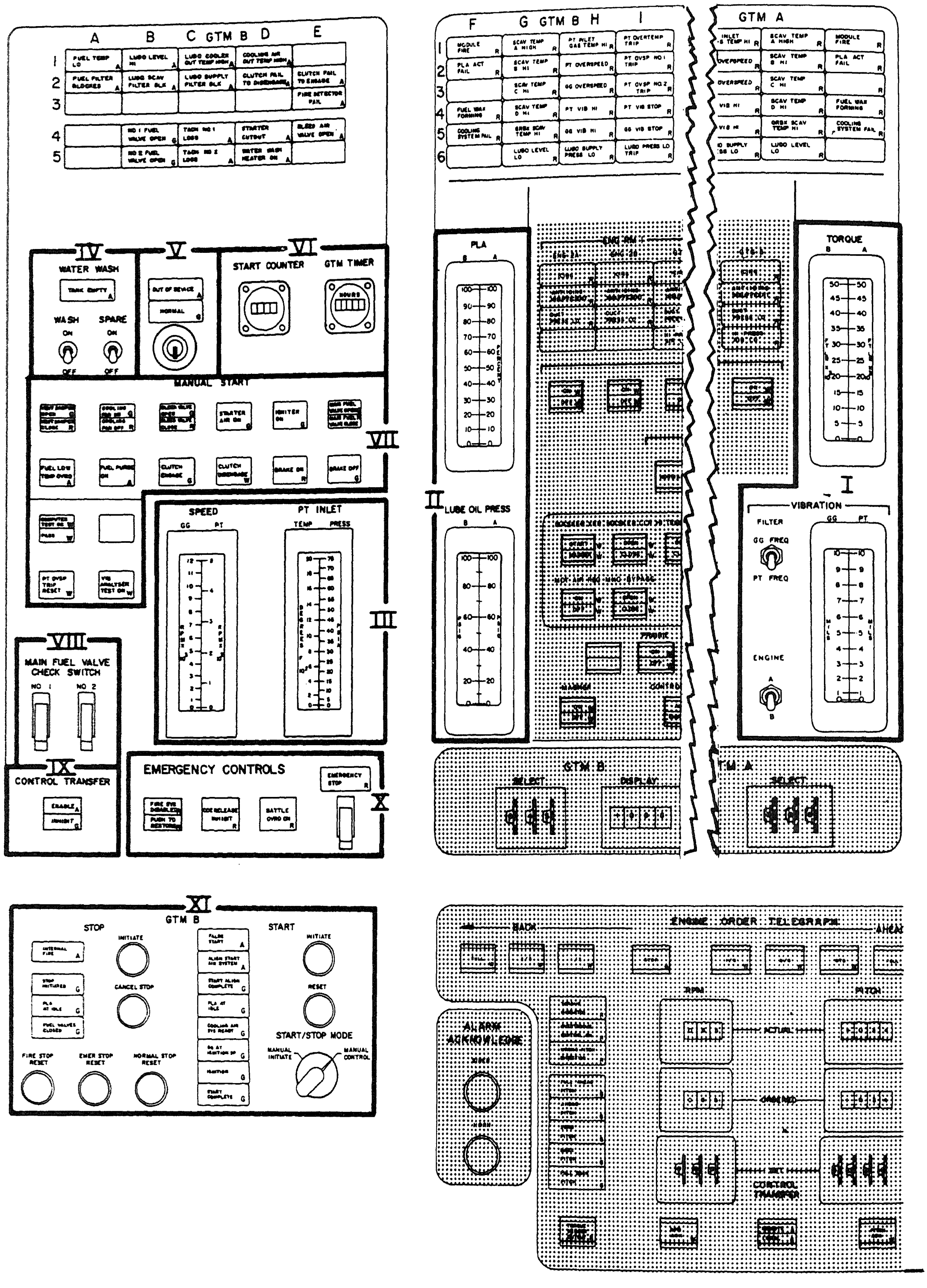

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Figure 6-11.—GTM B controls and indicators.

A-4. SUCTION STR ΔP HI (red). 4 psid

A-5. Blank

A-6. TK B SUCT VALVE OPEN (green)

A-7. TK B RECIRC VALVE OPEN (green)

A-8. TK B SUCT VALVE CL (red)

A-9. TK B RECIRCL VALVE CL (red)

B-1. PUMP A FAULT (red). Same as A-1

B-2. TANK A TEMP HI/LO (red). Same as A-2

B-3. Blank

B-4. DRAIN TANK LEVEL HI (red). 2.5 gallons in the leak detection tank

B-5. Blank

B-6. TK A SUCT VALVE OPEN (green)

B-7. TK A RECIRC VALVE OPEN (green)

B-8. TK A SUCT VALVE CL (red)

B-9. TK A RECIRC VALVE CL (red)

C-1. HEADER TEMP HI/LO (red). HI 130°F, LO 80°F

C-2. HEADER PRESS LO (red). 40 psig

C-3. HEATER TEMP HI (red). 140°F

C-4. FILTER WATER HI (red)

C-5. FILTER ΔP HI (red). 30 psid across the coalescer

C-6. Blank

C-7. Blank

C-8. FILTER A BLOCKED (amber). 25 psid across the A tower of the coalescer

C-9. FILTER B BLOCKED (amber). 25 psid across the B tower of the coalescer

The following is a description of the other controls which are a part of the FO control panel.

HEADER (TEMP AND PRESS) METER indicates the system temperature at the heater outlet and system pressure at the filter/coalescer outlet. This meter is independent of other electronics and operates even if other alarm circuitry is inoperative.

SERVICE TANK VALVES are covered toggle control switches. They command the fuel tank suction and recirculation valves open or closed.

PUMP is a set of control pushbuttons that control pump speed for both pumps.

EMERG TRIP are covered toggle control switches that command the emergency FO trip valves closed (you must open them manually).

PUMP MODE is a rotary select switch that allows for manual or automatic control of the fuel pumps. It selects the lead (primary) and standby pump.

CONTROL TRANSFER is a pushbutton control switch that transfers control of the FO system to the central control station.

GTM CONTROLS AND INDICATORS.—The GTM controls and alarm/status indicators are located toward the center of the console (figure 6-8 foldout). The controls and indicators for GTM B are on the left side of the console with the controls and indicators for GTM A on the right side.

Refer to figure 6-11, GTM B controls and indicators, and figure 6-12, GTM sensing points with controls and indicators, as we identify the GTM indicators and the parameters to activate them.

A-1. FUEL TEMP LO (amber) 80°F

A-2. FUEL FILTER BLOCKED (amber) 27 psid

A-3, 4, 5. Blank

B-1. LUBO LEVEL HI (amber) 40 gallons

B-2. LUBO SCAV FILTER BLK (amber) 20 psid

B-3. Blank

B-4. No. 1 FUEL VALVE OPEN (green)

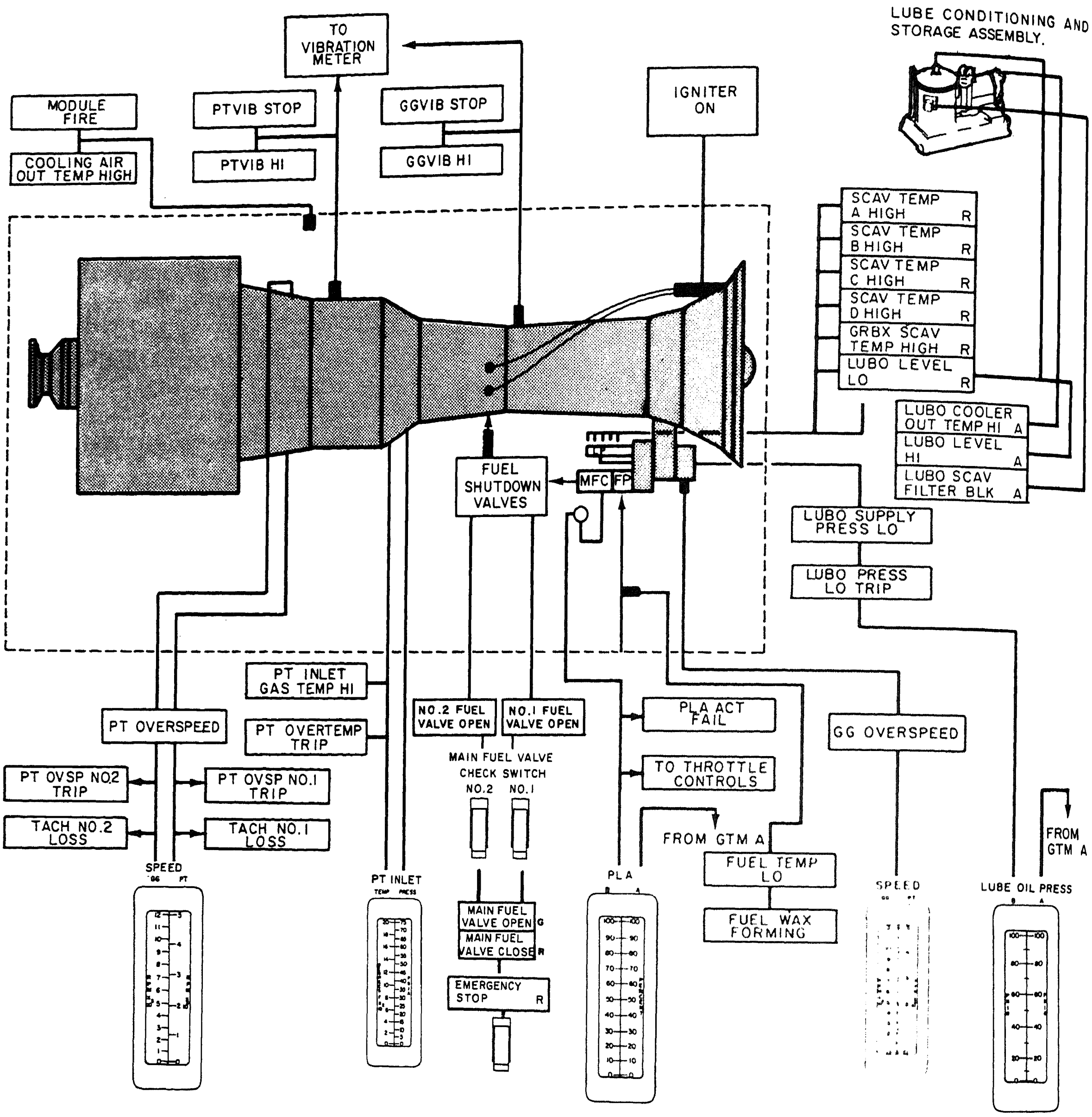

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Figure 6-12.—GTM sensing points.

B-5. No. 2 FUEL VALVE OPEN (green)

C-1. LUBO COOLER OUT TEMP HIGH (amber) 250 °F

C-2. LUBO SUPPLY FILTER BLK (amber) 20 psid

C-3. Blank

C-4. TACH No. 1 LOSS (amber). Power turbine speed (N_2) less than 100 rpm

C-5. TACH No. 2 LOSS (amber). Power turbine speed (N_2) less than 100 rpm

D-1. COOLING AIR OUT TEMP HIGH (amber) 350 °F

D-2. CLUTCH FAIL TO DISENGAGE (amber)

D-3. Blank

D-4. STARTER CUTOUT (amber)

D-5. WATER WASH HEATER ON (amber). (Not used)

E-1. Blank

E-2. CLUTCH FAIL TO ENGAGE (amber)

E-3. FIRE DETECTOR FAIL (amber). GTM fire sensor malfunction

E-4. BLEED AIR VALVE OPEN (amber)

E-5. Blank

F-1. MODULE FIRE (red). Flame detected by fire sensor or 400°F sensed by temperature switch

F-2. PLA ACT FAIL (red). Power level angle actuator voltage out of limits or an overtorque condition exists

F-3. Blank

F-4. FUEL WAX FORMING (red). Fuel temperature at the MFC is less than 60°F

F-5. COOLING SYSTEM FAIL (red). The cooling system fan pressure is out of limits or vent damper is not open

F-6. Blank

G-1. SCAV TEMP A HIGH (red) 300°F

G-2. SCAV TEMP B HIGH (red) 300°F

G-3. SCAV TEMP C HIGH (red) 300°F

G-4. SCAV TEMP D HIGH (red) 300°F

G-5. GRBX SCAV TEMP HIGH (red) 300°F

G-6. LUBO LEVEL LO (red) 8 gallons

H-1. PT INLET GAS TEMP HIGH (red) 1500°F ($T_{5.4}$)

H-2. PT OVERSPEED (red) 3700 rpm

H-3. GG OVERSPEED (red) 9700 rpm

H-4. PT VIB HIGH (red) 7 mils

H-5. GG VIB HIGH (red) 4 mils

H-6. LUBO SUPPLY PRESS LOW (red) 15 psig

I-1. PT OVERTEMP TRIP (red) 1530°F ($T_{5.4}$)

I-2. PT OVSP No. 1 TRIP (red) 3960 ± 40 rpm

I-3. PT OVSP No. 2 TRIP (red) 3960 ± 40 rpm

I-4. PT VIB STOP (red) 10 mils

I-5. GG VIB STOP (red) 7 mils

I-6. LUBO PRESS LOW TRIP (red) 6 psig

Refer to figures 6-11 and 6-12 as we describe the meters on the local control console. (The meters in Sections I and II are common. One side is used for GTM A and one side is used for GTM B. The meters in Section III are dual purpose meters but monitor only one GTM.)

Section I

Torque — The signals come from the GTM and are conditioned by the FSEE (torque computer section) and sent to the console for display. The torque meter reads in lb/ft and is the torque output of the power turbine.

Vibration — The signals come from vibration pickups on the LM2500. There are two pickups, one on the PT and one on the GG

Vibration—Continued	(figure 6-12). This meter has an engine select switch that allows you to select the engine to be monitored. This select switch and the meter do not affect the vibration high and vibration stop alarms described earlier. Another switch allows you to check the vibration at each frequency level. The vibration meter reads in mils (0.001 in.) peak to peak.

Section II

PLA	The signal comes from the PLA actuator and is sent to the console for display. The PLA meter reads in percentage of travel. This percentage is equal to degrees of travel of the power lever. 0% = 13° on DD-963, DDG-993, and CG-47. 0% = 13.5° on FFG-7. 100% = 113.5° on all classes.
Lube Oil Press	The signal comes from the lube oil pump, supply side (pump discharge), and is sent to the console for display. The lube oil pressure meter reads in psig.

Section III

PT Inlet	The signals come from the sensors in the turbine mid frame. The temperature sensors are thermocouples, and the pressure sensors are probes that pressurize a transducer. The temperature meter reads in degrees Fahrenheit, and the pressure meter reads in psia.
Speed	The signals originate at the GG and the PT, see figure 6-12. The GG speed pickup is located on the accessory gearbox. The PT speed pickups (2) are located in the turbine rear frame. The speed meter reads in rpm.

The next parts of the console to be discussed are the control sections, Sections IV through XI in figure 6-11.

Section IV

Water Wash	TANK EMPTY—shows the water wash tank is empty of water wash or rinse solution.
	WASH ON/OFF—is a toggle switch that opens or closes the water wash solenoid valves.
	SPARE—not used.

Section V

Key Switch	OUT OF SERVICE—shows that the key switch is in the OFF position. This position electronically locks out the air start valve so that the GTM cannot be started or motored. This position also shows OUT OF SERVICE at the central control console.
	NORMAL—shows that the key switch is in the ON position and the GTM is ready to operate, provided other external parameters are met.

Section VI

Start Counter GTM Timer	START COUNTER—registers a start each time $T_{5.4}$ is greater than 400°F and N_{GG} is greater than 4300 rpm for 0.25 seconds.
	GTM TIMER—shows running time for the GTM once the start counter requirements have been met.

Section VII

Manual Start
This panel is used with Section XI, Start/Stop mode

VENT DAMPER OPEN/VENT DAMPER CLOSE—is a split level control/status pushbutton that controls the GTM cooling system vent damper.

COOLING FAN ON/COOLING FAN OFF—is a split level control/status pushbutton that controls the GTM cooling fan.

BLEED VALVE OPEN/BLEED VALVE CLOSE—is a split level control/status pushbutton that controls the GTM bleed valve.

STARTER AIR ON—is a control/status pushbutton that controls the air start valve.

IGNITER ON—is a control/status pushbutton that controls the igniters.

MAIN FUEL VALVE OPEN/MAIN FUEL VALVE CLOSE—is a split level control/status pushbutton. It controls both fuel valve No. 1 and No. 2 at the same time.

FUEL LOW TEMP OVRD—is a control/status pushbutton. It provides a logic override step that allows the GTM to be started, in manual initiate or auto initiate, with fuel temperatures below 80 °F.

FUEL PURGE ON—is a control/status pushbutton. It allows cold fuel to be dumped from the GTM to the waste oil drain tank. This button is normally used when the module fuel temperature is below 80 °F.

CLUTCH ENGAGE—is a control/status pushbutton that engages the GTM clutch.

CLUTCH DISENGAGE—is a control/status pushbutton that disengages the GTM clutch.

BRAKE ON—is a control/status pushbutton that applies the GTM PT brake.

BRAKE OFF—is a control/status pushbutton that releases the GTM PT brake.

COMPUTER TEST ON/PASS—is a split level control/status pushbutton. It starts a test of the torque computer and shows if the test was passed.

PT OVSP TRIP RESET—is a control/status pushbutton that resets the main fuel valves after an overspeed trip. NOTE: Do not depress this pushbutton until the engine comes to a complete stop.

VIB ANALYSER TEST ON—is a control/status pushbutton that tests the vibration analyzer circuits in the local control console.

Section VIII

Main Fuel Valve Check Switch(es)

No. 1—is a double position toggle switch that closes number 1 main fuel valve.

No. 2—is a double position toggle switch that closes number 2 main fuel valve.

Section IX

Control Transfer

ENABLE/INHIBIT—is a split level control/status pushbutton that enables the transfer of controls of the GTM controls to the central control console.

Section X

Emergency Controls (These controls are available at both consoles continuously)

FIRE SYS DISABLED/ PUSH TO RESTORE—is a split level control/status pushbutton. The top level alarms when there is a cooling system failure. A normal stop will also be started. Under this condition emergency trip switches are inoperative. If the cooling system is repaired, by activating the pushbutton you may then cancel the normal stop and the fire system is restored.

CO_2 RELEASE INHIBIT—is a control/status pushbutton that prevents the CO_2 fire system from releasing. You have 20 seconds to disable the CO_2 release after the module fire alarm occurs.

BATTLE OVRD ON—is a control/status pushbutton that prevents the following:

- GG High Vibration Trip
- PT High Vibration Trip
- GTM Cooling System Failure Trip
- PT Overtemperature Trip
- GTM Low Lube Oil Press Trip
- Fire Stop
- PT Torque Limiting in FSEE
- PT Speed Limiting in FSEE
- PT Acceleration Limiting in FSEE
- Fail-to-Idle Protection in FSEE

EMERGENCY STOP—is a double position toggle switch that provides an operator activated manual emergency stop. The associated alarm indicator alarms each time an emergency stop is activated. Emergency fuel trip switch activation will also generate an emergency stop alarm unless the cooling system failure exists or a normal stop is in progress (if in a normal stop, the trip valve closes, but no alarm is sounded).

Section XI

Stop

The stop half of the panel has five pushbuttons, three status indicators, and one alarm indicator. The pushbuttons are active only when the start/stop mode switch is in the manual initiate position.

INITIATE—is a pushbutton that starts a normal stop of the GTM.

CANCEL STOP—is a pushbutton that cancels a normal stop of the GTM.

FIRE STOP RESET, EMER STOP RESET, NORMAL STOP RESET—are logic circuitry reset pushbuttons for each of these sequences (active even in manual control mode).

INTERNAL FIRE—is an alarm that indicates an internal (post-shutdown) fire. If 3 minutes after shutdown $T_{5.4}$ is greater than 700 °F, the alarm will activate.

STOP INITIATED—is a status indicator that shows a stop has been initiated.

Stop—Continued

PLA AT IDLE—is a status indicator that shows when the PLA reaches idle. At idle a 5-minute cool-down timer begins.

FUEL VALVES CLOSED—is a status indicator that shows when the cool-down period is over. After cool down, the fuel valves close, which secures the GTM.

Start

The start half of the panel has two pushbuttons, a rotary select switch, two alarm indicators, and six status indicators. The two pushbuttons are active only in the manual initiate mode.

INITIATE—is a pushbutton that initiates a manual initiate start.

RESET—is a pushbutton that resets the logic circuitry for the manual initiate start sequence.

START/STOP MODE—is a rotary select switch that allows you to select the starting and stopping mode.

FALSE START—is an alarm that indicates one of two alarm conditions: (1) Less than 1200 N_{GG}, 20 seconds after the start air valve opens; (2) $T_{5.4}$ less 400 °F, 40 seconds after main fuel valves open (1200 N_{GG}).

ALIGN START AIR SYSTEM—is a status and an alarm indicator. As a status indicator, it comes on steady to show the air start system is being aligned for a start. As an alarm indicator, it comes on flashing to show the air start system will not properly align (either valves failed to properly position or anti-icing air is on).

START ALIGN COMPLETE—is a status indicator that illuminates after the logic circuits check alignment of the following:

- GTM in service
- Start air system aligned
- HP start priority check
- Fuel temperature
- Bleed air valve closed

PLA AT IDLE—indicates PLA AT 0%.

COOLING AIR SYS READY—shows the vent damper is open and the cooling fan is operating properly.

GG AT IGNITION SP—shows that GG speed is greater than 1200 rpm.

IGNITION—shows $T_{5.4}$ is greater than 400 °F.

START COMPLETE—shows GG speed is greater than 4300 rpm. (Once the start logic has been reset, electronically, the above status indicators extinguish.)

AIR/MAIN REDUCTION GEAR CONTROLS AND INDICATORS.—In the center of the console are the alarms for the air systems and the MRG/shafting. Also located in this section are controls and indicators for the intake system, and the starter, prairie, and masker air systems.

Figure 6-13 shows air controls, alarms, and MRG alarms. Refer to this figure as we describe the parameters for each indicator or control pushbutton.

A-1. SHAFT TORQUE HI (red). This alarm indicator is set to alarm at different set points for one engine operation (split plant) and two engine operation (full power). The split plant set point is 0.92×10^6 lb/ft (920,000). The full power set point is 1.5×10^6 lb/ft (1,500,000).

A-2. THRUST BRG TEMP HI (red). This is a summary alarm that monitors three thrust bearings. Two of the thrust bearings are in the two GTM clutch/brake assemblies. The third thrust bearing is the main thrust bearing on the MRG. The alarm set point is 165 °F.

A-3. JOURNAL BRG TEMP HI (red). This is a summary alarm that monitors all (26) MRG journal bearings. The alarm set point is 165 °F.

A-4. START AIR OVERTEMP (red). The signal for this alarm originates at an RTE in the start air system to the GTMs. The alarm set point is 450 °F.

A-5. Blank.

A-6. TURN GEAR ENGAGED (red). This status indicator shows when the MRG turning gear is engaged.

B-1. SHAFT SEAL PRESS LO (red). This alarm indicates when cooling/sealing water pressure to the propeller shaft seal drops below 12 psig.

B-2. SHAFT BRG TEMP HI (red). This alarm indicates when the temperature of the line shaft bearing(s) is above 180 °F. For the port shaft of DD-963 class ships this is a summary alarm. This means that any of the four bearings on that shaft can activate the alarm.

B-3. PRAIRIE AIR TEMP HI (red). This alarm indicates prairie air temperature above 100 °F.

B-4. MASKER AIR OVERTEMP (red). This alarm indicates masker air temperature above 200 °F.

B-5. BLEED PRESS LO (red). This alarm indicates bleed air pressure in the header is below 40 psig.

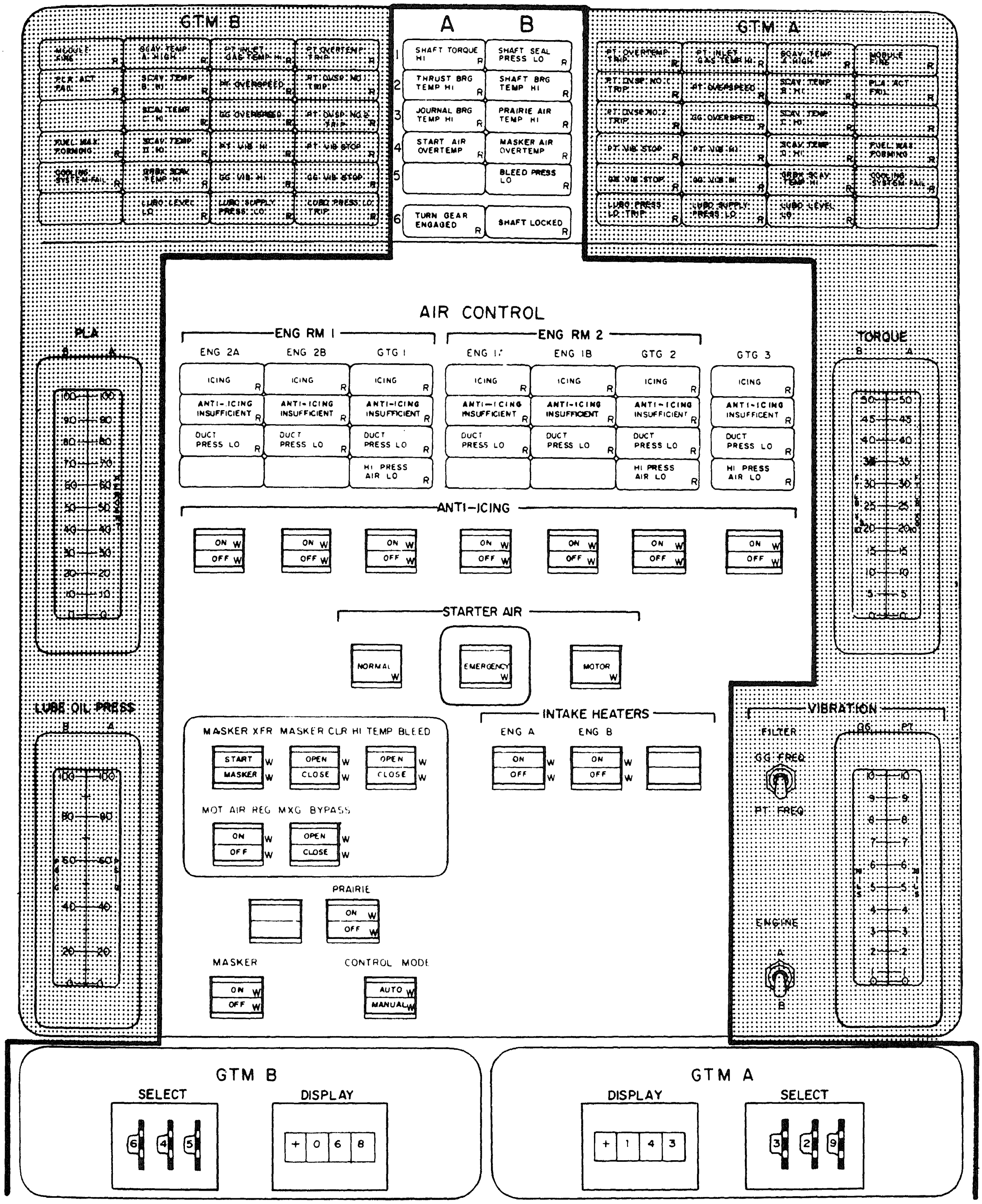
B-6. SHAFT LOCKED (red). This status indicator shows when the shaft lock mechanism is engaged at the MRG turning gear.

The next section we will discuss is the air control. Figure 6-13 shows three alarms for each main gas turbine and four alarms for each GTG. The air control alarms are at all propulsion consoles. This means that when an alarm occurs, it is displayed at each local control console and at the central control console.

The first set of main gas turbine alarms is for the intake ducting and anti-icing. The GTG alarms are identical except that an HP air alarm is added.

Air Control Alarms (Main Gas Turbine).—Descriptions of these alarms follow.

ICING (red)	This alarm is a combination of two parameters, temperature and humidity. These conditions are sensed by a detector mounted in the GTM enclosure barrier wall. The alarm set point is less than 41 °F and greater than 70% humidity.
ANTI-ICING INSUFFICIENT (red)	This alarm activates if anti-icing air is on and the intake air temperature is not greater than 36 °F. The sensor for this alarm is just below the anti-icing manifold in the intake.
DUCT PRESS LO (red)	This alarm activates if the pressure in the intake duct drops to 8 inches of H_2O vacuum.



286.106

Figure 6-13.—Air controls, alarms, and MRG alarms.

Air Control Alarms (Gas Turbine Generators).—Descriptions of these alarms follow.

ICING (red)	This alarm activates if the intake air to the GTG drops to 36°F.
ANTI-ICING INSUFFICIENT (red)	This alarm activates if the intake air remains at 36°F and the anti-icing system is on.
DUCT PRESS LO (red)	This alarm activates if the pressure in the intake duct drops to 8 inches of water.
HI PRESS AIR LO (red)	This alarm activates if the HP air bank pressure drops to 1000 psig.

The next section is anti-icing. This section is similar to the air control section. Like the air control section, you can turn on anti-icing bleed air for any running gas turbine at either PLCC or the PACC. The split level control/status anti-icing pushbuttons are all identical.

In the next section we will discuss the STARTER AIR pushbuttons. These three pushbuttons are used with the CONTROL MODE pushbutton at the bottom of the center panel. For the starter air pushbuttons to be active, the control mode button must be in the auto position.

Starter Air Pushbuttons.—Descriptions of these pushbuttons follow.

NORMAL	Selecting this pushbutton allows the logic, in the console, to align the bleed valves properly for a GTM start.
EMERGENCY	Selecting this pushbutton allows HP air to be available for a GTM start and high speed motoring in the event there is no bleed air and post-shutdown fire exists. NOTE: Some classes of ships do not have an HP air starting capability.
MOTOR	Selecting this pushbutton allows the logic in the control to align the bleed valves properly for a motoring cycle of the GTM.

After the starter air section are the control pushbuttons for each bleed air valve, prairie air, and masker air control.

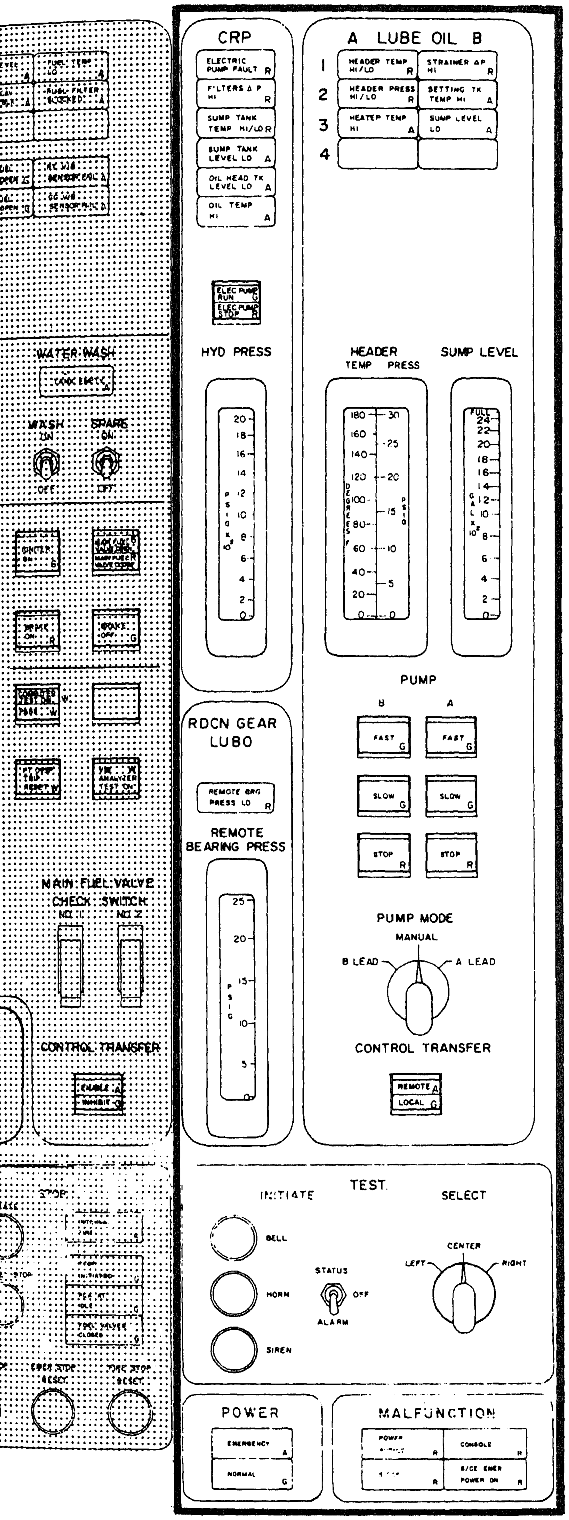
The next section we will discuss is the INTAKE HEATERS pushbuttons. These split level control/status pushbuttons control the intake air heaters. These electric heaters are located on the louvers at the high hat intake. During cold weather, these heaters prevent ice formation on the intake. If the heater controller is in the remote position, the heaters will turn on when anti-icing is activated.

The last section of this panel is the demand display indicator (DDI). The DDI system is an operator information system. The system is used to verify parameters, check the system's operation, and to troubleshoot system malfunctions. Any parameter monitored can be displayed at any DDI location. The DDI system uses a three-digit address to probe the memory of the computer and find the value of the parameter. The DDI displays it in the display windows. To use the DDI system, you

1. determine the address for the required parameter;
2. dial the address in the SELECT thumbwheels; and
3. observe the value of the parameter in the display window.

In the DDI system the values are continually updated at the rate of four times a second.

CRP AND LUBE OIL SYSTEMS' CONTROLS AND INDICATORS.—The controls of the CRP and lube oil systems (figure 6-14) are located on the upper right panel of the console. The CRP section has one control pushbutton, one pressure meter, and six alarm indicators. The lube oil section has six control pushbuttons, one two-in-one meter and one liquid level meter, six alarm indicators, one rotary select switch, and one control transfer pushbutton. Also there is a small



286.107

Figure 6-14.—CRP and lube oil controls and alarms.

panel for the MRG remote bearing which has a pressure meter and an alarm indicator.

Refer to figure 6-14 as we discuss the CRP system first, the lube oil system second, and the remote bearing section last.

CRP Alarms and Indicators.—Descriptions of these alarms and indicators follow.

ELECTRIC PUMP FAULT (red)	The CRP pump must be running and pressure must be below 100 psig for more than 5 seconds.
FILTERS ΔP HI (red)	Summary alarm which monitors three sets of filters on the hydraulic oil pressure module (HOPM). There are two types of filters on the HOPM, two sets of 40 micron filters, and one set of 10 micron filters. The alarm set points are 40 psid (40 micron) and 70 psid (10 micron).
SUMP TANK TEMP HI/LO (red)	Hi 160°F/Lo 60°F.
SUMP TANK LEVEL LO (amber)	Less than 500 gallons.
OIL HEAD TK LEVEL LO (amber)	Low oil level in the CRP head tank. The set point is 10 gallons.
OIL TEMP HI (amber)	Oil temperature from the hydraulic pump to the system is greater than 180°F.

The next indicator is the ELEC PUMP RUN/ELEC PUMP STOP split level control indicator pushbutton. This pushbutton controls the CRP electric hydraulic oil pump located on the HOPM. The only meter associated with the CRP is the hydraulic pressure meter in this section. The pressure shown is the HP oil at the output of the HOPM to the oil distribution box on the propeller shaft.

Lube Oil Alarms and Indicators.—Descriptions of these alarms and indicators follow.

A-1. HEADER TEMP HI/LO (red). Monitors the temperature of the MRG lube oil header. The set points are HI 130°F and LO 90°F. Inhibits clutch brake operation at 130°F unless the CCS key switch is enabled.

A-2. HEADER PRESS HI/LO (red). Monitors oil pressure in the MRG header. The set points are HI 27 psig and LO 15 psig. Inhibits clutch brake operation at 15 psig unless the CCS key switch is enabled.

A-3. HEATER TEMP HI (amber). Monitors the output temperature of the lube oil service system heater. The set point is 170°F.

A-4. Blank.

B-1. STRAINER ΔP HI (red). Monitors the MRG lube oil strainer differential pressure (ΔP). The set point is 10 psid.

B-2. SETTING TK TEMP HI (amber). Monitors the lube oil service system settling tank temperatures. The set point is 170°F.

B-3. SUMP LEVEL LO (amber). Monitors the lube oil level in the MRG. The set point is 1400 gallons.

B-4. Blank.

The HEADER TEMP/PRESS meter monitors the temperature and pressure of the lube oil at the MRG header. The temperature side reads in degrees Fahrenheit and the pressure side reads in pounds per square inch (gauge).

The SUMP LEVEL meter monitors the level of the MRG lube oil sump. The meter reads in gallons.

PUMP is a set of six control pushbuttons which control pump speed for both pumps.

PUMP MODE is a rotary select switch which allows for manual or automatic control of the lube oil pumps.

CONTROL TRANSFER is a pushbutton control switch. It transfers control of the lube oil system to the central control console.

Reduction Gear Alarm and Indicator.—RDCN GEAR LUBO is a small panel with an alarm indicator and a pressure meter. The parameters for this panel are sensed at the lower outboard first reduction gear bearing. The alarm indicator set point is 5 psig. The meter reads 0 to 25 psig. Because there is a certain amount of head pressure in the lube oil supplied to this bearing and its sensor, the meter tends to read 1 to 3 psig greater than lube oil header pressure.

Directly below the CRP, lube oil, and reduction gear panel is a small test panel. This panel is used to lamp test all the indicators and alarms on the local control console.

ENGINE ORDER TELEGRAPH (EOT) PANEL.—When the ship control console does not have throttle control, the officer of the deck must inform the station in control of speed requirements. This is done through EOT. The EOT is a communications system. It transmits propulsion command information between the station in command (ship control console [SCC]) and the station in control of the throttles (local control console or the central control console).

Figure 6-15 shows the EOT panel. The EOT panel has two major sections, the standard order pushbutton/status indicators and the digitized EOT. Operation and further explanation of the EOT panel will be covered later in this chapter under Propulsion Plant Operations.

The EOT panel also contains three alarm indicators, five status indicators, the ALARM ACKNOWLEDGE pushbuttons, a TORQUE SENSOR CUTOUT pushbutton, and a CONTROL TRANSFER pushbutton/status indicator.

TORQUE MISMATCH (red)	Indicates a mismatch of torque between the PT and the propulsion shaft. These values are electronically measured by the FSEE and the shaft torque sensor. The alarm set point is more than 25% difference of the two torque values for greater than 60 seconds.

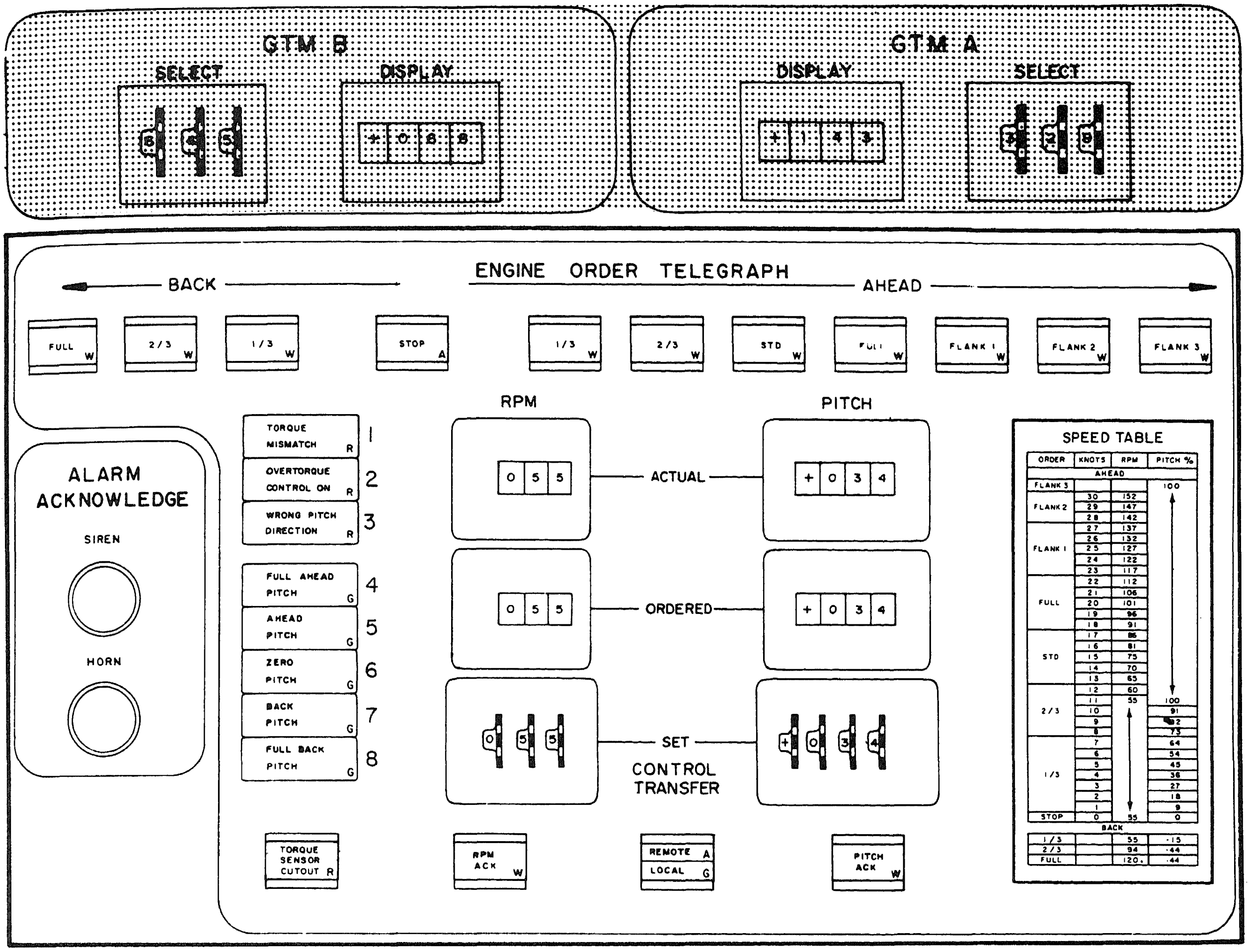


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Figure 6-15.—Engine order telegraph (EOT) panel.

OVERTORQUE CONTROL ON (red) — Indicates that overtorque control has been activated either in the FSEE (PT torque limiting) or by the console electronics (shaft torque limiting). This indicator illuminates when limiting is occurring. If after 20 seconds the overtorque condition still exists, the alarm will sound.

WRONG PITCH DIRECTION (red) — Indicates a difference between the commanded pitch, the position of the pitch control lever, and the actual pitch of the propeller. If the wrong direction condition exists for longer than 20 seconds, an audible alarm is sounded. If a wrong direction condition exists and shaft rpm is greater than 60, the console electronics will bring the PLA to idle.

FULL AHEAD PITCH (green) — Shows +100% propeller pitch.

AHEAD PITCH (green)	Shows +16% to +100% propeller pitch.
ZERO PITCH (green)	Shows −16% to +16% propeller pitch.
BACK PITCH (green)	Shows −16% to −49% propeller pitch.
FULL BACK PITCH (green)	Shows −49% propeller pitch.

The ALARM ACKNOWLEDGE pushbuttons are the main interface between you and the control console. Each time an alarm is activated, an audible alarm sounds. Amber (potential danger) alarms sound a horn and red (danger) alarms sound a siren. When any alarm activates, the proper procedures to follow are listed below.

1. Identify the alarm condition. The alarm indicator will come on flashing, and the audible will sound.

2. Acknowledge the alarm. Depress the proper alarm acknowledge pushbutton. This action silences the audible and causes the alarm indicator to glow steadily.

3. Investigate the alarmed condition following EOCC.

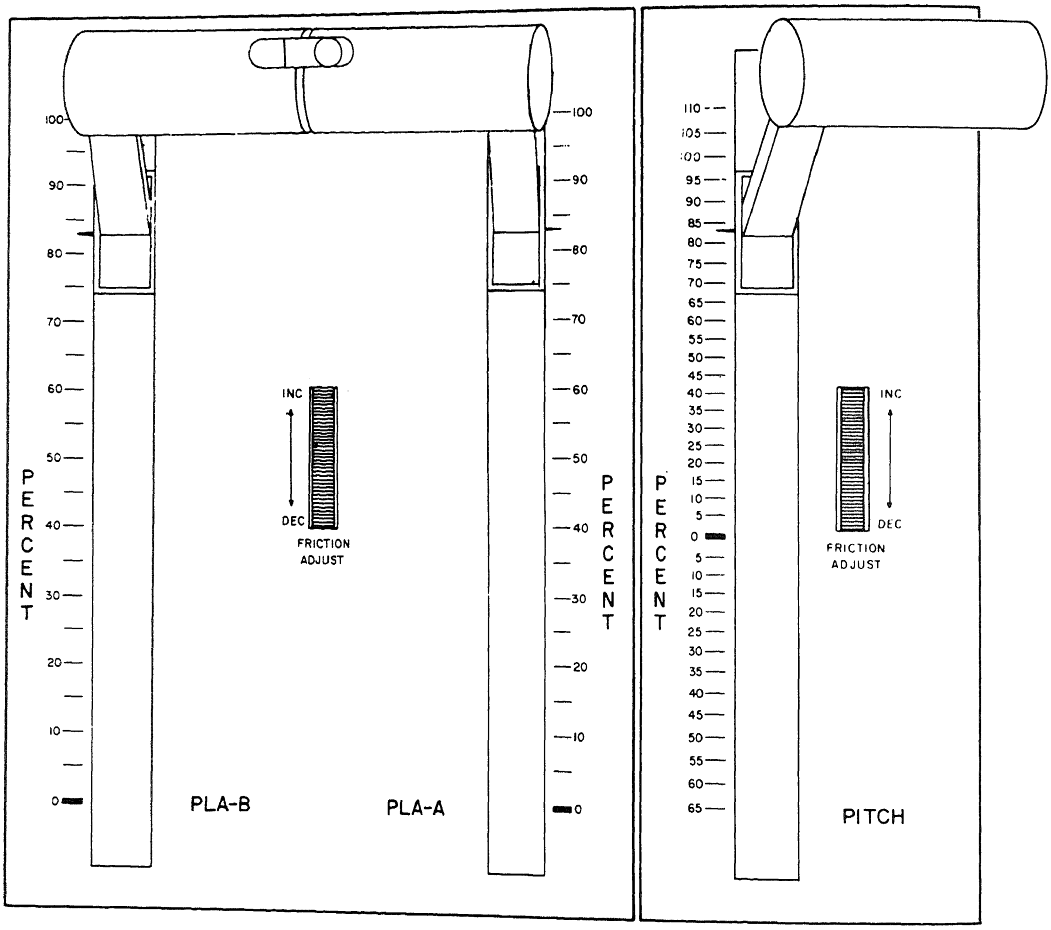

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Figure 6-16.—Throttle/pitch controls.

The TORQUE SENSOR CUTOUT is a pushbutton switch that electronically overrides shaft torque limiting. Shaft torque is sensed by a torsion meter installed on the propeller shaft. If propeller shaft torque becomes too great, an electronic signal is generated to limit PLA of the GTM. This action limits the power of the GTM until it is within normal power limits. When the torque sensor cutout is activated, propeller shaft torque is NOT electronically limited.

The CONTROL TRANSFER LOCAL/REMOTE pushbutton is the transfer button for the following functions.

1. GTM controls, start/stop functions
2. Clutch/brake controls
3. CRP pump control
4. EOT control

The control transfer button is used with the GTM ENABLE/INHIBIT pushbuttons discussed in GTM controls and indicators.

THROTTLE AND PITCH CONTROLS.— The throttle and pitch controls (figure 6-16) are levers which are electronically connected to the PLA of the GTM and to the CRP electronic enclosure, respectively. The throttle levers are graduated in percentage of PLA from 0% to 100% for each PLA. The pitch lever is graduated in percentage of pitch travel from 0% to 110% (ahead) and from 0% to −65% (astern).

Propulsion Local Control Electronics Enclosure (PLCEE)

The PLCEE contains electronics to convert the 120 volt a.c. to voltage levels used by the electronic and electrical components of PLOE. If the 120 volt a.c. input should fail, the PLCEE is automatically supplied by a 150 volt d.c. UPS system.

LM2500 OPERATION FROM THE LOCAL CONTROL CONSOLE

The following paragraph is a procedure for manually starting a gas turbine propulsion engine on a DD-963 class ship. You should use this procedure for training purposes only with this RTM. This procedure does not supersede the EOSS or any shipboard operating orders or instructions.

The local control console is capable of operating all equipment within the engine room associated with that console. As we have already mentioned, there are two modes of control available for starting and stopping a GTM: (1) manual control where you complete the steps to starting or stopping a GTM; (2) manual initiate control where you initiate the start or stop, and electronic logic completes the required steps. In the following section, we will present the steps and requirements for completing a manual start or stop.

SUPPORT SYSTEM ALIGNMENT

Perhaps the most vital step in preparing to start any GTE is the alignment of the support systems. You should use the EOSS to validate each auxiliary following the desired operating condition. You can align, validate, start, and then operate some support systems in an automatic condition. Other support systems you have to operate manually and monitor often. It is very important for you to have all operating support systems thoroughly validated and aligned before starting a GTE.

GTM MANUAL START SEQUENCE

A sequence of steps and events must take place at a specific time to start a GTE. If these events do not take place at their proper time, the GTE could malfunction or not start. Figure 6-17 is a start sequence flow diagram for a manual start; you should use this figure with figure 6-18, flow chart symbols.

Figure 6-17 shows seven steps at the beginning of the start sequence. These steps are preconditions that should be satisfied before the actual first step begins. An explanation of the seven steps, reading from left to right, follows.

Step 1—Align GTM support systems. All support systems must be aligned, validated, and operating normally.

Step 2—Align air start system. The air start system must be aligned, validated, and ready to operate in the selected mode.

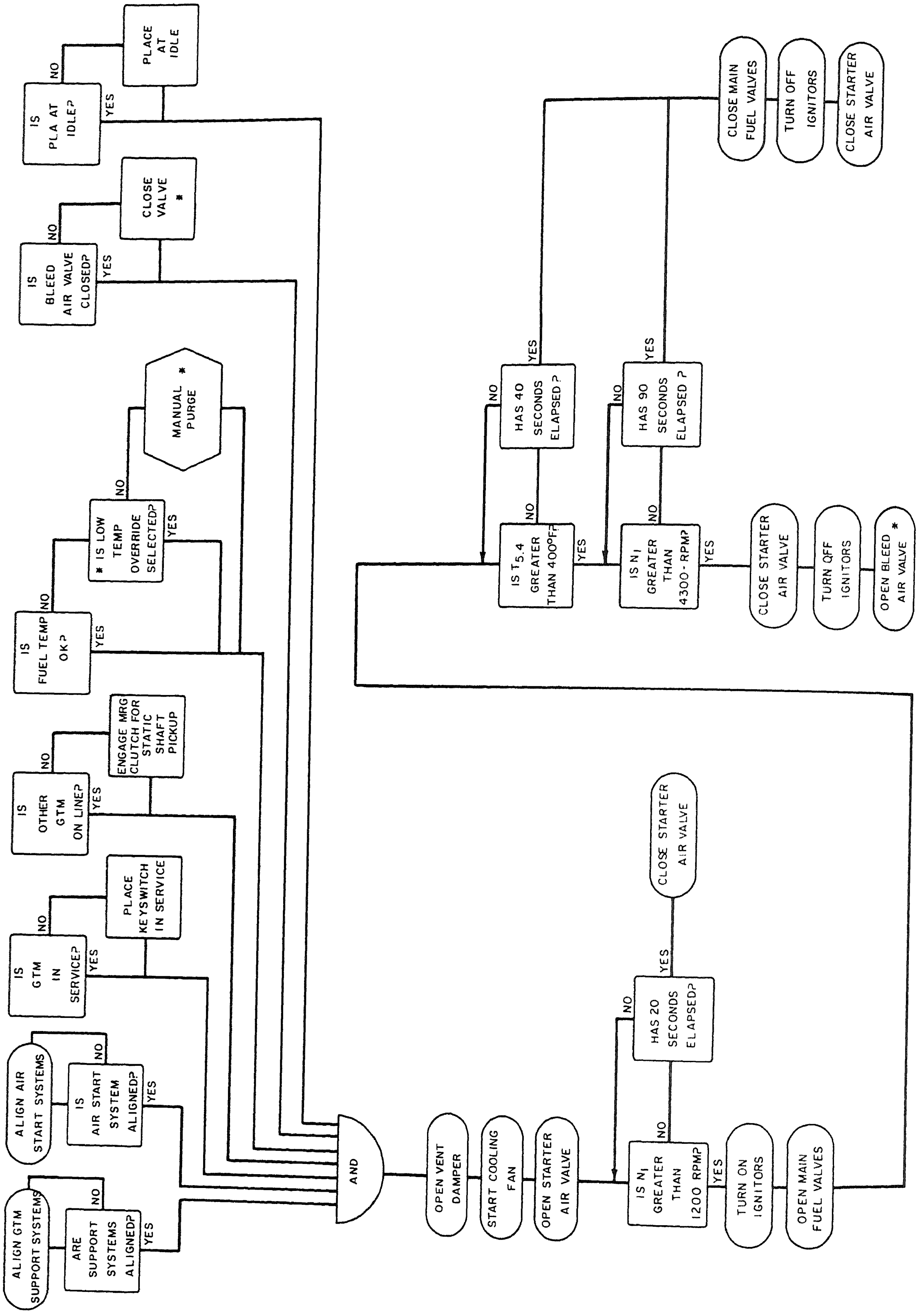

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Figure 6-17.—Manual start sequence flow diagram.

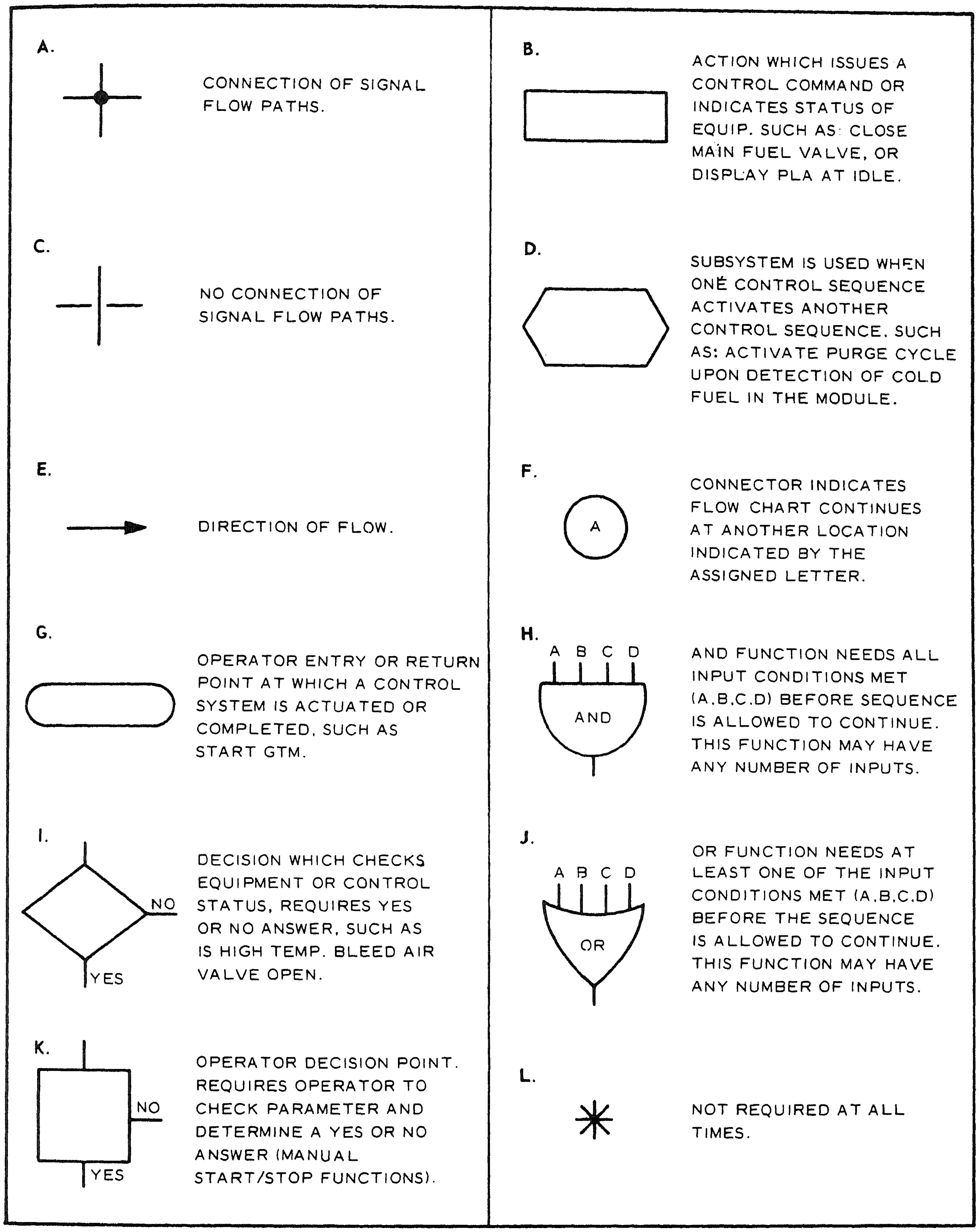

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Figure 6-18.—Flow chart symbols.

Step 3—Is the GTM in service? This decision point requires you to check the GTM key switch and place it in service.

Step 4—Is the other GTM on line? This decision point requires you to check the status of the other GTM in this engine room. If the other GTM is on line, no action is required. If the other engine is static, the GTM to be started must have its clutch engaged before start-up. The procedure is unique to DD-963 and DDG-993 class ships and is referred to as static shaft pickup.

Step 5—Is the fuel temperature OK? This decision point requires you to check the fuel temperature and determine if it is acceptable. If the fuel temperature is within limits, proceed to the next step. If the fuel temperature is too low, you are required to select fuel low temp override (as ordered by the EOOW) or perform a manual fuel purge cycle. (The manual purge cycle discards the cold fuel in the GTM. It replaces the cold fuel with hot fuel from the FO service system.) These are not required steps for an emergency start.

Step 6—Is the bleed air valve closed? This decision point requires you to verify the position of the bleed air valve and close it if necessary. This is not a required step for an emergency start.

Step 7—Is PLA at idle? This decision point requires you to ensure that the PLA is in the idle position.

Once all the preconditions have been met, you can begin the actual steps of starting the engine. The description of each of the steps of engine starting will follow, from top to bottom, the manual start sequence flow diagram (figure 6-17).

The first series of steps to start the GTM is the cooling air system. The first step is to open the vent damper and start the cooling air fan. Once this is done, you are ready for the actual starting. Remember, events must take place at a specific rpm and within a certain amount of time. If not, the engine will fail to start or malfunction.

The next step in starting the GTM is to open the starter air valve. At the same instant, you must also start a stopwatch or observe a clock to meet time requirements. Once the starter air valve is open, you should observe the GG speed meter for movement. As the meter rises, you can be sure you have GG rotation. When you have rotation, the next indication to check is the lube oil pressure meter. This meter should begin to move up as the GG speed increases above 500 rpm. If no oil pressure indication is present by the time the GG reaches 1100 rpm, close the starter air valve. Investigate the problem.

When the GG reaches 1200 rpm, the time frame is less than 20 seconds from 0 rpm. If the GG has not reached 1200 rpm within 20 seconds, close the starter air valve. Once the 1200 rpm window has been met, the igniters are turned on and the main fuel valves are opened. You must follow this sequence. If you reverse the steps, a hot start could occur.

Next, observe the temperature ($T_{5.4}$) window. $T_{5.4}$ must be greater than 400 °F in less than 40 seconds after the igniters are turned on and the main fuel valves opened. This shows you that the engine has "lit off." If this temperature window is not met, take the following actions.

- Close main fuel valves
- Turn off igniters
- Realign air system for motoring

You should take these actions in this order to prevent unburned fuel from remaining in the combustor.

Next, observe the speed window at 4300 rpm, GG speed. This window must be met in less than 90 seconds. This time frame is taken from the time the starter air valve is opened. If this speed window is not met, the action is the same as before.

- Close main fuel valves
- Turn off igniters
- Realign air system for motoring

Meeting the 4300 rpm speed window indicates that the engine is rotating freely and has attained greater than self-sustaining speed.

Your next actions are (1) close the starter air valve to secure starter operation; (2) turn off the igniters (they are no longer required because engine combustion is self-sustaining); and (3) open the bleed air valve, if required.

DLE OPERATION CHECKS

Once the GTM is started, you must check a umber of parameters to ensure the engine is perating properly. Generally, these idle checks are outlined in the EOSS. You should check all idle check parameters with the digital display indicators and the meters. Table 6-1 shows the parameters you should check and the observations you should make.

Table 6-1.—LM2500 Normal Idle Operating Parameters

Step No.		Parameter	Observation
A.		Assure that startup is completed.	N_{GG} 4900-5000 rpm
B.		Observe the following parameters:	
	1.	Lube Oil Pressure	16 to 30 psig NOTE Under certain lube oil temperature conditions you may operate the gas turbine with lube supply pressure below alarm level of 15 psig, but not below 6 psig.
	2.	PT Tempt ($T_{5.4}$)	1000 °F max CAUTION If indication of compressor stall is encounter, perform emergency shutdown. NOTE A compressor stall at idle can be recognized by one or a combination of any of the following symptoms: higher than normal $T_{5.4}$, higher than normal fuel manifold pressure, or GG speed does not increase or is sluggish when throttle is advanced from idle position.
	3.	Fuel Manifold Press (FMP)	230-350 psig NOTE A minimum of 70 psig fuel manifold pressure is acceptable for 10 seconds maximum during deceleration to idle setting.
	4.	GG Speed (N_{GG})	4900-5000 rpm
	5.	Observe above parameter, $T_{5.4}$, FMP, and N_{GG}, together for indication of compressor stall.	Higher than normal $T_{5.4}$, higher than normal fuel manifold pressure, or GG speed does not increase or is sluggish when throttle is advanced from idle position.
	6.	(1) PT Speed (N_{PT}) (clutch and brake disengaged)	1600-2200 rpm
		(2) TACH Loss Indicators (N_{PT})	TACH Loss No. 1 and No. 2 lamps not illuminated

Table 6-1.—LM2500 Normal Idle Operating Parameters—Continued

Step No.	Parameter	Observation
7.	GG Vibration	4 mils max CAUTION Avoid extended operation at max vib limit. NOTE There are two vibration pickups. One is located on the GG and the other is on the PT. Each pickup senses both GG and PT vibrations. A tracking filter for each pickup separates GG from PT vibrations depending on vibration frequency. Limits apply to frequency and not pickup location.
8.	PT Vibration	7 mils max
9.	Oil Tank Level	Visible in 19 gal sight glass NOTE The sight glass levels are based on usuable oil and are not the absolute levels of oil in the tank. Eight gallons are not usable. Usable range of oil in terms of absolute level is 8 to 32 gallons. This corresponds to 0 to 24 gallons of sight glass level. LUBO LEVEL LO alarm on at 8 gallons nominal absolute; LUBO LEVEL HI alarm at 40 gallons nominal absolute. Service oil tank if oil is not visible in 19-gallon sight glass.
10.	Lube Oil Heat Exchanger Outlet Temperature	135°-220°F max
11.	Scavenge Oil Temperature	200°-300°F normal all sumps (A, B, C, D) and gearbox, 340°F max
12.	Fuel Inlet Temperature	30° to 100°F max
13.	Fuel Filter Differential Pressure	7 psid max at idle. Alarm (FUEL FILTER BLOCKED) above 27 psid. Bypass opens at 35 psid, resets at 27 psid.
14.	Scavenge Filter Differential Pressure	5 psid max at idle. Alarm (LUBO SCAV FILTER BLK) above 20 psid
15.	Lube Supply Filter Differential Pressure	5 psid max at idle. Alarm (LUBO SUPPLY FILTER BLK) above 20 psid.
16.	Ventilation Exit Air Temp	Variable, 350°F max
17.	GG inlet Temp (T_2)	Approximately equal to outside air temperature (OAT)

LUTCH ENGAGEMENT

Now that the GTM is running and the idle ecks have been done, the engine is ready to be gaged to the MRG and power train. The MRG ts as a coupler between the GTEs and the propeller shaft. This coupling or transmission link done by the MRG. Basically, it has two main puts and one main output. The two inputs are e PT couplings from each of the GTEs. The ain output is the ship's main propeller drive aft.

It is impractical for the main propeller shaft turn at the same rpm as the GTE. So, there about 21.5 to 1 gear reduction between the put and the output drives.

The gearing is permanently attached to the opeller drive shaft. Therefore, there must a means of separating and/or connecting e PT shafts to the gearing. To make this nnection or separation, a clutch mechanism provided for each PT shaft. When cometely engaged, the clutch provides a direct nnection between the PT shaft and the main duction gearing.

Each PT shaft also has its own brake system. ie PT brake is a disk-type brake mechanism at is physically attached to the PT shaft d the MRG. The engaging or disengaging either the brake or clutch is done at the cal control console. If the PT brake is applied ile the clutch is disengaged, it will stop the PT aft.

There are two different ways of engaging e clutch: (1) static shaft engagement or) dynamic shaft engagement. When both GTMs e secured or when one GTM is running but t turning the propeller shaft, the static shaft ndition exists (static means not moving). r the static shaft engagement, the clutch must engaged before starting the GTM. The reasons r this are very complex and will not be scussed here. Remember, if the shaft is tic, the clutch must be engaged before starting e GTM. Dynamic (moving) shaft clutch engageent can be done any time after the GTM has en started.

For proper clutch engagement, an initial condition must be set. That condition is PT brake ON, clutch DISENGAGED. To engage the clutch from this condition, only the CLUTCH ENGAGE pushbutton need be depressed. Logic automatically moves the PT brake off and then engages the clutch. In some cases, during dynamic clutch engagements, you may release the PT brake before engaging the clutch.

PROPULSION PLANT OPERATIONS

Before complete operation can begin, we need to discuss "breaking" the static shaft. During static shaft startup, the GTM was started and the clutch engaged. But generally the GTM will not produce enough net horsepower to start the shaft turning. Once you have completed idle checks, the throttle for the operating engine can be SLOWLY advanced to about 5 to 7 percent. You should maintain the throttle at this setting until the shaft starts turning. Then adjust the throttle to maintain the ordered shaft rpm. Sometimes the 5 to 7 percent throttle setting will not provide enough power to "break" the shaft. In this case, advance the throttle above 7 percent. Monitor N_1 closely. It should not exceed 7000 rpm. The throttle should never exceed 17 percent PLA without shaft rotation. If you advance the throttle to the 17 percent level and the shaft still does not turn, then secure the engine. If 17 percent PLA is exceeded with the shaft stopped, the engine will secure on an unidentified stop. Next, investigate the problem. Once the GTM is running properly and the clutch is engaged, operation of the propulsion plant (GTM(s), MRG, controllable pitch propeller) may begin.

NOTE: The motion and speed of the ship are directly dependent on the speed (rpm) of the shaft and the pitch of the propeller. The speed of the shaft generally remains constant to a given point on the speed table and then increases. The pitch of the propeller varies from 0 to +100 percent, or −49 percent, depending on the required speed.

Look at the relationship between rpm and pitch/speed (knots) in table 6-2. Note that shaft speed remains constant at 55 rpm through 11 knots and then begins to increase. Also, note that propeller pitch increases through 100 percent at the 11-knot speed. Commands for ship's speed are transmitted from the officer of the deck on the ship's bridge to the operating console by the EOT. There are two types of EOTs—the standard order EOT and the digitized EOT.

Table 6-2.—DD-963 RPM and Pitch/Speed Table

SPEED TABLE

ORDER	KNOTS	RPM	PITCH %
AHEAD			
FLANK 3			100
	30	152	
FLANK2	29	147	
	28	142	
	27	137	
	26	132	
FLANK I	25	127	
	24	122	
	23	117	
	22	112	
	21	106	
FULL	20	101	
	19	96	
	18	91	
	17	86	
	16	81	
STD	15	75	
	14	70	
	13	65	
	12	60	
	11	55	100
2/3	10		91
	9		82
	8		73
	7		64
	6		54
	5		45
1/3	4		36
	3		27
	2		18
	1		9
STOP	0	55	0
BACK			
1/3		55	-15
2/3		94	-44
FULL		120	-44

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The standard order EOT consists of standard engine commands such as ahead 1/3, back 2/3, and ahead full. These commands are transmitted to the console on the standard order push-button/status indicators. When the order is transmitted, the appropriate pushbutton comes on flashing and the bell sounds. The order is acknowledged by depressing the flashing standard order pushbutton. This action silences the bell. You can then carry out the order by moving the throttle and/or pitch lever(s). Once the ordered speed has been met, the flashing indicator lights up steadily.

Digitized EOT provides digital RPM and PITCH commands in one-character increments. These commands are transmitted to the console on the ORDERED digital indicators on the EOT panel (figure 6-15). When the digital EOT is used, the bridge transmits the order. The RPM ACK and/or the PITCH ACK pushbutton(s) flash(es) and the bell(s) sound(s). Also, the ordered DDI changes to the new commanded speed and/or pitch. You move the SET thumbwheels to the position shown by the ORDERED DDIs. Then the order is acknowledged by depressing the RPM and/or PITCH ACK pushbutton(s). This action stops the indicator and silences the bell.

In the manual throttle mode, you have complete control of the shaft speed and the propeller pitch. To vary shaft speed, move the PLA throttle lever(s) while observing shaft speed (ACTUAL DDI) to maintain the ordered rpm. You can latch the two throttle levers together for two-engine operation or unlatch them for single-engine operation. To vary propeller pitch, you move the pitch lever to the desired setting. Propeller pitch settings respond rapidly and should move to the commanded position within 30 seconds.

You need much practice to move the throttle levers and pitch lever together to get the exact setting in the shortest time. Remember, when you operate this system, your goal is to answer the bells as fast and accurately as possible. Accuracy is the main consideration. Never let accuracy suffer just to be in a hurry. Also, remember that you always add pitch before power and remove power before pitch to prevent overspeed conditions.

During the routine course of operating the ropulsion plant, you can expect numerous status, varning, and alarm indicators to come on. As ach of these alarms happens, you must think of ne possible problem areas and check these conitions. If the problem area is checked out romptly, there is a smaller chance of major amage to equipment. The accepted method of larm investigation follows.

1. Note the alarm before acknowledging it. ometimes, alarms will clear when they are cknowledged. These are known as transient larms.
2. Acknowledge the alarm.
3. Verify the parameter using another means, uch as DDI, meter, or gauge.
4. Go to the equipment and investigate the larmed condition, if possible.
5. Report the condition of the equipment and ne findings to the engineer officer of the watch n the central control station.

When assigned to a propulsion plant watch tation during operations, you must be alert and ware of all conditions within the watch area. To e a good watch stander, you must be completely amiliar with all the equipment and systems in ne watch station. You should make frequent nspections of the watch station area. These nspections are to ensure that machinery is perating properly. They are to keep the operator nformed of all operation conditions. Frequent ours of the watch station can alert the operator o abnormal conditions before they turn into najor malfunctions.

ECURING THE PLANT

To stop a GTM under normal conditions, you nust perform certain steps at specific times in the top sequence. Refer to figure 6-19, manual stop equence flow diagram, while following the text.

The first step after determining the engine(s) o be secured is to disengage the clutch. One of ne clutch disengagement permissives is PLA at dle. So you must place the throttle at idle and nen disengage the clutch. Once the clutch is isengaged, shut the bleed air valve.

When these pre-securing steps have been comleted, leave the PLA at idle. Start a 5-minute timer. The 5 minutes provides a stabilization period for the GTM. During the 5-minute period, the engine cools down and all parameters stabilize. During the last 2 minutes of the cool down, check the parameters listed in table 6-3.

After you have checked those parameters and the 5-minute timer has expired, close the main fuel valves. As soon as the GG has coasted to a stop, place the PT brake on.

The next step is to start a 3-minute timer. When this timer expires, the temperature at $T_{5.4}$ should be less than 700 °F. If the temperature is less than 700 °F, the support systems can be secured, if required. If this GTM is to be placed in standby, most support systems should remain operating. If the temperature is greater than 700 °F, an internal (post-shutdown) fire is present. The accepted method of extinguishing an internal fire follows.

1. Trip the fuel emergency trip valve.
2. Shut the manual fuel supply valve.
3. Motor the gas turbine until $T_{5.4}$ drops below 400 °F.
4. Investigate the cause of the fire.

The first two steps in this procedure are to ensure that NO fuel is going to the GTM. The motoring step does two things—it blows the fire out and it provides cooling air for the internal parts. There are many causes of internal fires, but we will not discuss them here.

SUMMARY

Up to this point, we have discussed engine-room or local operation. As a GSE 3 or 2, you may be assigned watches at these watch stations. The material presented so far has given you a basic understanding of what operations may be done at the engine-room consoles. Remember, before you attempt any operation at these consoles, you must be familiar with and use the EOSS.

We will discuss central control station operations for Spruance class in chapter 9 and FFG-7 class in chapter 10. This chapter has only attempted to describe LM2500 operation at its lowest control point, the local operating station. Do not attempt LM2500 operation until you understand how the control stations operate. By the knowledge learned in this chapter, by using

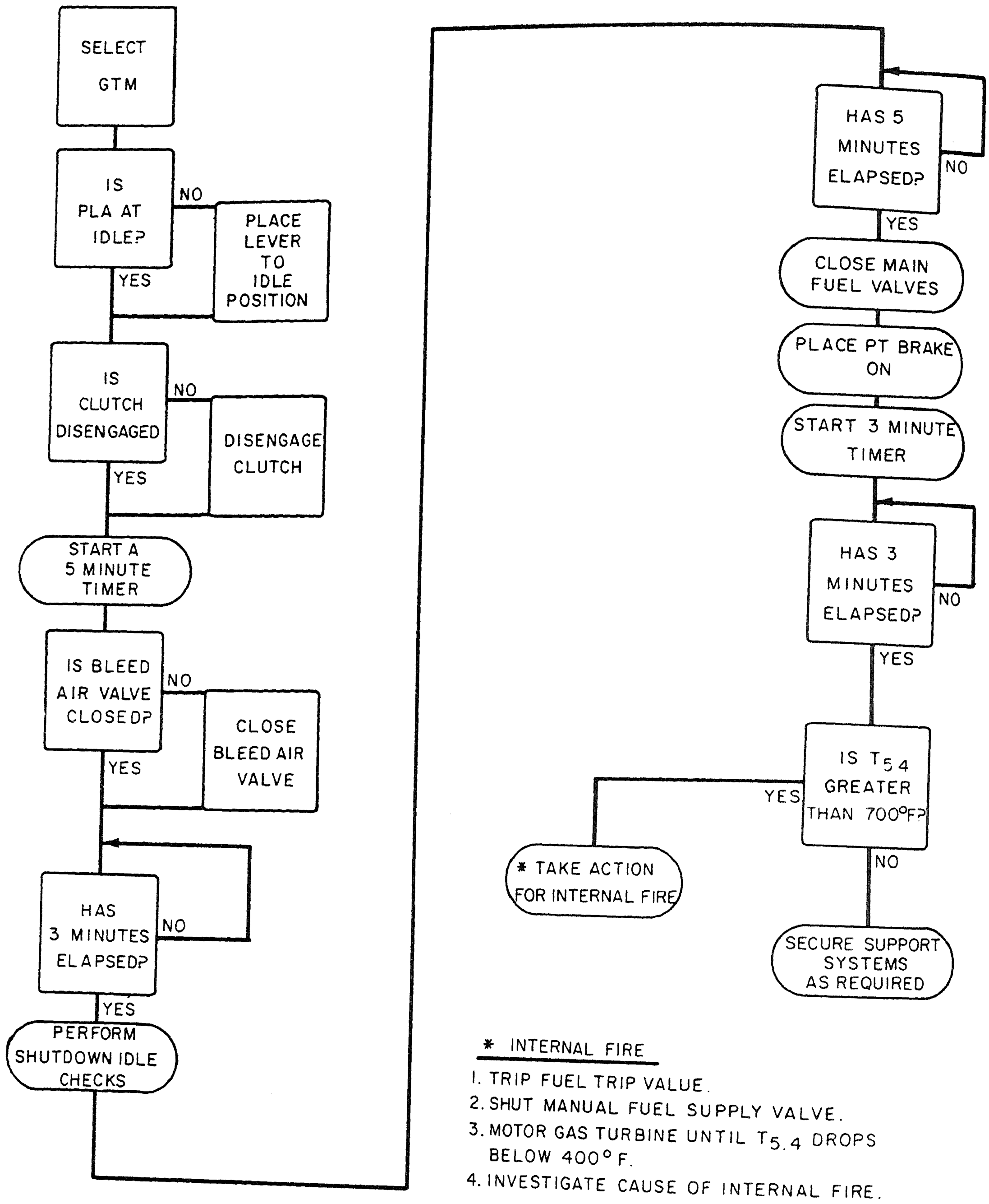

Figure 6-19.—Manual stop sequence flow diagram.

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Table 6-3.—LM2500 Normal Shutdown Idle Checks

Parameter	Observation
A. Set gas turbine at idle power	PLA at idle discrete signal is generated
B. Operate gas turbine at idle power for 5 minutes. During the last 2 minutes observe the following parameters:	
1. Oil pressure	16 psig min
2. Fuel manifold pressure	230-350 psig max NOTE A minimum of 70 psig fuel manifold pressure is acceptable for 10 seconds maximum during deceleration to idle setting
3. N_{GG}	4900-5000
4. $T_{5.4}$ Temp	1000°F max
5. N_{PT} (clutch and brake disengaged)	1600-2200 rpm
6. GG Vibration	4 mils max NOTE There are two vibration pickups. One is located on the GG and the other is on the PT. Each pickup senses both GG and PT vibrations. A tracking filter for each pickup separates GG from PT vibrations depending on vibration frequency. Limits apply to frequency and not pickup location
7. PT vibration	7 mil max
8. Lube oil heat exchanger	135°-220°F normal 250°F max
9. Scavenge oil temperature	200°-300°F normal 340°F max
10. Ventilation exit air temp	Variable, 350° max
11. Fuel filter differential pressure	7 psid max at idle. Alarm above 27 psid (bypass opens at 35 psid, resets at 27 psid)
12. Scavenger filter differential	5 psid max at idle. Alarm above 20 psid (bypass opens at 25 psid, resets at 20 psid)
13. Lube supply filter differential pressure	5 psid max at idle. Alarm above 20 psid (bypass opens at 25 psid, resets at 20 psid)
C. De-energize main fuel valves	$T_{5.4}$ drops below 400°F and N_{GG} and N_{PT} decelerates
D. Observe $T_{5.4}$ for 3 min after shutdown	700°F max

PQS and EOSS, and your experience under instruction watches, you should be able to readily qualify in your ship's engine-room watch station.

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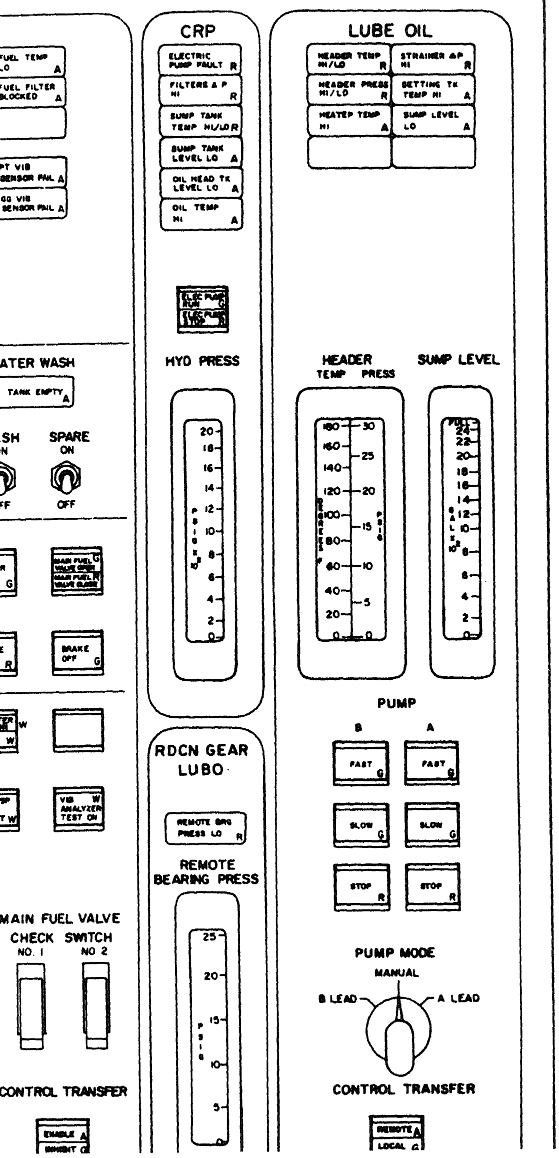

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CHAPTER 7

FREE STANDING ELECTRONIC ENCLOSURE

The free standing electronic enclosure (FSEE) s the major electrical interface to the LM2500 ;T. As a GSE, you will perform many adjust- nents and checks on this very important piece of ngine-room equipment. The FSEE controls the .M2500 electronically through many complicated ircuits. It is also the connection point for the hip's propulsion consoles to input control com- nands and output parameters. Many of the cir- uits we will describe are used on all FSEE models. Iowever, one section of the FSEE, the start/stop equencer, is found only on the FFG-7 class ships. ;ach FSEE controls two LM2500 GTs, or in other vords, there is one FSEE per gas turbine engine oom. By properly maintaining the FSEE, you will nsure the LM2500 operates at peak performance evels, has available all its protective circuits, and an be relied upon for operation at any time. The 'SEE is a fairly complex and sensitive unit. You hould only attempt adjustments on it if you are horoughly familiar with it. Therefore, you should vork with a more experienced FSEE technician efore making adjustments on your own. Then, nly make adjustments following the LM2500 echnical manual.

In this chapter we will cover the various cir- uits of the FSEE. By reading this and completing he associated NRCC, you should be able to nderstand the working of these circuits. We will lso discuss how these circuits can change the ngine's performance. Knowing this information vill enable you to quickly diagnose FSEE nalfunctions. We will also discuss the FSEE djustments to give you a brief idea how to test nd set these circuits. This chapter is ONLY a earning tool. It is not meant to and never should e used to replace the required technical manuals. 'ou should use the required technical manuals vhen actually maintaining the FSEE.

Since the FSEEs are fairly identical on all classes of ships, we will discuss the basic FSEE, pointing out the differences as necessary. As mentioned earlier, the major difference is the use of the start/stop sequencer on the FFG-7 class. Another difference is the use of an acceleration limiting circuit in all classes but the FFG-7.

FSEE CONSTRUCTION

The FSEE (figure 7-1) is a solid-state unit mounted in a steel enclosure. Figure 7-1 shows an FFG-7 FSEE. It has two card racks (one per engine) and two power supplies. Each card rack has the control circuits for one engine. Fourteen circuit cards in each rack are used for GT opera- tion. These are letter designated for reference and ease of identification.

Letter Designation	Name
A	PLA Actuator Board No. 1
B	Torque, Speed, and Accel- eration
C	PLA Actuator Board No. 3
D (two per card rack)	Electronic Overspeed Con- trol Switch
E	Signal Conditioner
F	Input/Output No. 1
H	Control

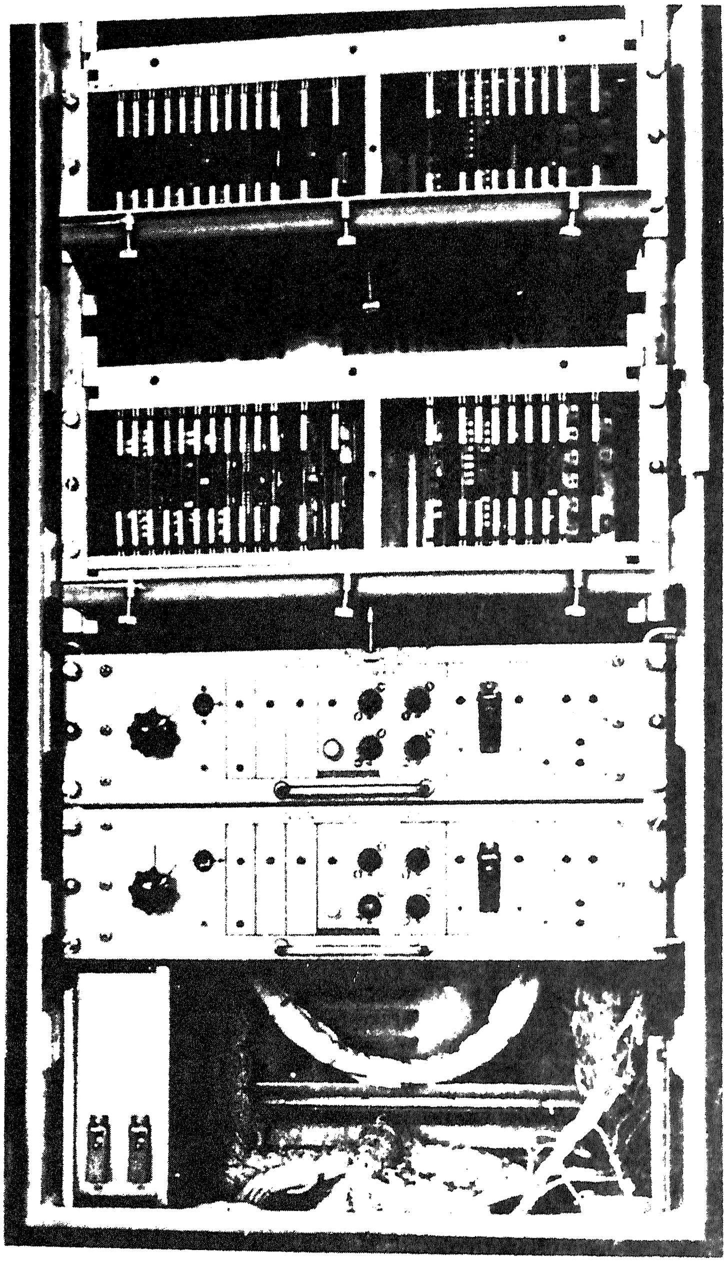

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Figure 7-1.—FFG-7 free standing electronic enclosure.

Letter Designation	Name
J	Arithmetic
K	Address Control
L	Memory
N	Input/Output No. 2
P	Sub Command
T	−12 and −15 volt d.c. power converter

The other nine circuit cards in each rack are used for the start/stop sequencer. These cards are:

Letter Designation	Name
X	Signal Conditioner No. 1
Y	Signal Conditioner No. 2
Z	Signal Conditioner No. 3
AB	Logic Card 1
AD	Logic Card 2
AE	Logic Card 3
AC	Logic Card 4
AA	Transmitter (10-volt d.c.)
V	Thermocouple Amplifier
	D. C. Converter 1ard No. 4

The FSEE also has two d.c. power distribution assemblies and an a.c. power distribution assembly.

The FSEEs used on the DD-963, DDG-993, and CG-47 class ships (figure 7-2) have fewer components. This is because the start/stop sequencing on these ships is done in the PLCC. Only one circuit card rack is used. It has the circuit cards for both GTs. One common card, the M card, is used by both GTs on these classes but is not used on FFG-7 FSEEs. The cards used in this FSEE are:

Letter Designation	Name
A (1 per GT)	PLA Actuator Board No. 1
B (1 per GT)	Torque, Speed, and Acceleration Limiter
C (1 per GT)	PLA Actuator Board No. 3
D (2 per GT)	Electronic Overspeed Control Switch
E (1 per GT)	Signal Conditioner
F (1 per GT)	Input/Output No. 1
H (1 per GT)	Control
J (1 per GT)	Arithmetic
K (1 per GT)	Address Control
L (1 per GT)	Memory
M (1 per FSEE)	Overspeed Indicator Pull-Up Resistor
N (1 per GT)	Input/Output No. 2
P (1 per GT)	Sub Command

This FSEE also has a dual redundant power supply set. It supplies power to the FSEE circuit cards and the engine. We will discuss this power supply in greater depth later in this chapter.

FSEE INPUT/OUTPUT SIGNALS

Because of the use of the start/stop sequencer, the FSEE on the FFG-7 has many more inputs and outputs than does the DD/DDG/CG FSEEs. Several inputs and outputs are the same for both FSEEs.

The FFG-7 FSEE uses 37 inputs per engine. These come from both the control consoles and LM2500. Many of these inputs are used by the

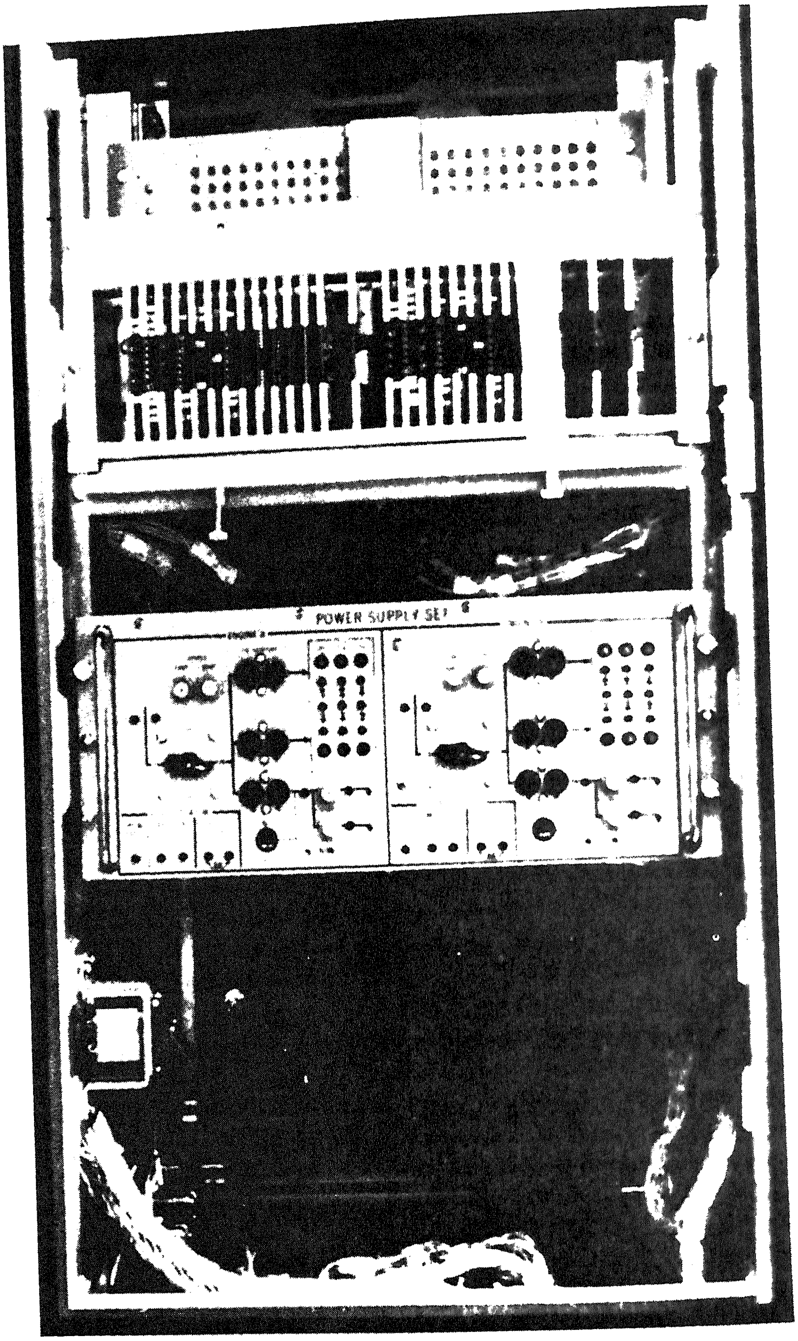

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Figure 7-2.—Free standing electronic enclosure found on DD-963, DDG-993, and CG-47 class ships.

start/stop sequencer for manual control of the engine. Some of the inputs are used to monitor engine operation. The remaining ones are used to control the engine. The main controlling outputs to the engine from the FSEE are PLA commands and fuel valve operation. The PLA actuator is the main interface between the FSEE control functions and the MFC. Signals from the FSEE set the PLA which, in turn, positions the MFC. The MFC is preset to schedule fuel at the proper level for each PLA setting. Varying the PLA setting will accelerate or decelerate the engine. Many inputs to the FSEE control this PLA setting to set the engine at its proper power level.

PLA OPERATION

The PLA actuator (figure 7-3) is an electromechanical motor actuator. It connects the FSEE's PLA electronics to the MFC. Its components have a d.c. torque motor, a line filter, a d.c. tachometer generator, a position feedback potentiometer, and a gear coupling.

The motor is driven by the PLA actuator drive signal from the FSEE. It supplies the torque needed to move the MFC lever at the proper rate. The direction the motor rotates is determined by the polarity of the d.c. voltage from the FSEE. The velocity of the motor is proportional to the amplitude (strength) of the drive signal. The motor is connected to the output drive lever by a four-gear drive train that steps down motor speed and increases torque.

The input voltage range is between 0 to ± 23 volts d.c. This will turn the motor between 0 and 900 rpm which, when stepped down through the gear train, equals about 0 to 16 rpm. The MFC lever will be at steady state only when the input signal is 0 volts d.c. The PLA actuator is capable of turning 15 rpm, or 90 degrees per second, clockwise or counterclockwise with a ± 23-volt d.c. input signal. PLA rate limit circuits, discussed later, limit the rate increase to 2.1 volts per second in the increasing direction and 9 volts per second in the decreasing direction. This limits the PLA actuator movement to 8.2 degrees per second increasing and 73.9 degrees per second decreasing. The motor can run into external hard stops and remain stalled at full voltage without damage. The input signal is filtered by an RFI

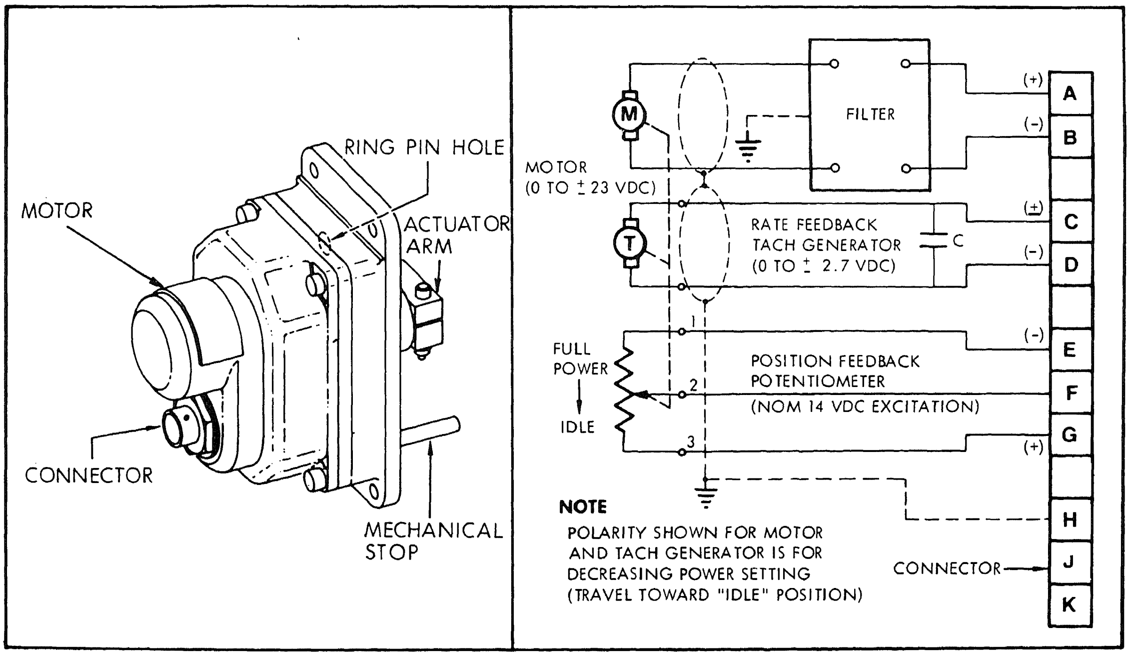

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Figure 7-3.—Power lever angle actuator.

input filter. The filter reduces the possibility of external electrical interference from affecting the PLA input signal.

The PLA actuator also incorporates two feedback circuits that input the FSEE. These are used to tell the FSEE the position and the rate of travel of the PLA actuator.

The rate of travel is measured by a tachometer generator. This is a d.c. generator that is directly coupled to the PLA motor shaft. This generator outputs a d.c. voltage proportional to motor speed which is also proportional to the output shaft speed. The polarity of this voltage depends on the direction the motor shaft turns. The range of the output of the generator voltage is 0 to ± 2.7 volts d.c. for output shaft speed of 0 to 15 rpm. The signal is sent to the FSEE. It is commonly called rate feedback.

The other feedback signal is used to tell the FSEE the position of the PLA actuator output shaft. This signal originates from a linear nonwire-wound variable resistor. The pot slider position of the resistor is controlled by the actuator output shaft. Since the PLA actuator output lever only moves about 100 degrees, the potentiometer is driven by a set of gears to increase its accuracy. The potentiometer is allowed to move about 227 degrees. A reference voltage of 14 volts d.c. (nominal) is applied to each end of the potentiometer. The feedback signal is taken from the sliding arm. This voltage divider action is proportional to the position of the PLA output shaft.

The PLA is physically mounted on the engine's fuel pump. The output lever is connected to the MFC power lever. Rig features allow locking of the PLA actuator output lever at a position of 113.5 ± 1 degree. This is used when setting the linkage between the PLA actuator and the MFC. Rigging of the PLA is also done electrically and should be done following the manufacturer's technical instructions.

PLA ACTUATOR ELECTRONICS

The PLA actuator circuits are used to control the MFC within predetermined safe limits. The PLA electronics has 13 control, detection, and monitoring functions. These PLA circuits are found on three circuit cards in the FSEE (the A, B, and C cards) and associated circuitry in the d.c. power distribution assemblies.

In the following paragraphs we will discuss the PLA circuit. Figure 7-4 (a foldout at the end of this chapter) is a block diagram of the PLA circuit. The components we will discuss are keyed by parenthetical numbers to the figures. To make the description and explanation easier for you to understand, the PLA circuit is subsectioned into 14 illustrations (figures 7-5 through 7-18). Please follow these figures as we discuss the various components.

Potentiometer Slider Control

The main purpose of the potentiometer (or pot) slider control is to provide the FSEE with feedback from the PLA actuator as to its position. (Since it is interlocked to the MFC, it also gives feedback to the MFC's position.) This signal is compared to the command rate limited signal in an error detector (summation amplifier No. 1) for determining the difference between the actual PLA position and the commanded position. The pot slider control also provides uplink (out to the propulsion consoles) of the actuator position and signals that are used in the C card (PLA actuator card No. 3).

The pot slider signal (figure 7-5) is a d.c. position feedback signal from the variable pot in the PLA actuator (1). This signal is proportional to the MFC lever position. It represents the lever position from zero to full power. This signal is sent to a unity gain isolation amplifier (2). This provides for a high impedance load for the variable pot. Figure 7-5 shows the PLA servo loop block diagram. Notice where position feedback is sent to the junction at error detector No. 1 (3). The uplink signal is conditioned by a lever shifter/driver (4). The lever shifter/driver changes the uplink signal to a low output impedance signal. This signal is capable of driving the circuits in the propulsion consoles.

The pot slider signal represents minimum (idle) to maximum (full power) MFC positions. This signal is sent to the idle position detector (5) (to output PLA at idle signals). It is then compared to a reference signal. This sets the threshold of the detector to a point 2 degrees above the idle position. If the MFC lever position is below this

threshold, the idle position detector operates a relay (6) in the power distribution assembly. The relay outputs the PLA at idle signal. If the lever is above this position, the detector has no output. This opens the relay and removes the PLA at idle signal.

Command Control

The position of the MFC lever is controlled through the PLA actuator by the command signal (figure 7-6). The command rate limiter limits the rate of change of the lever.

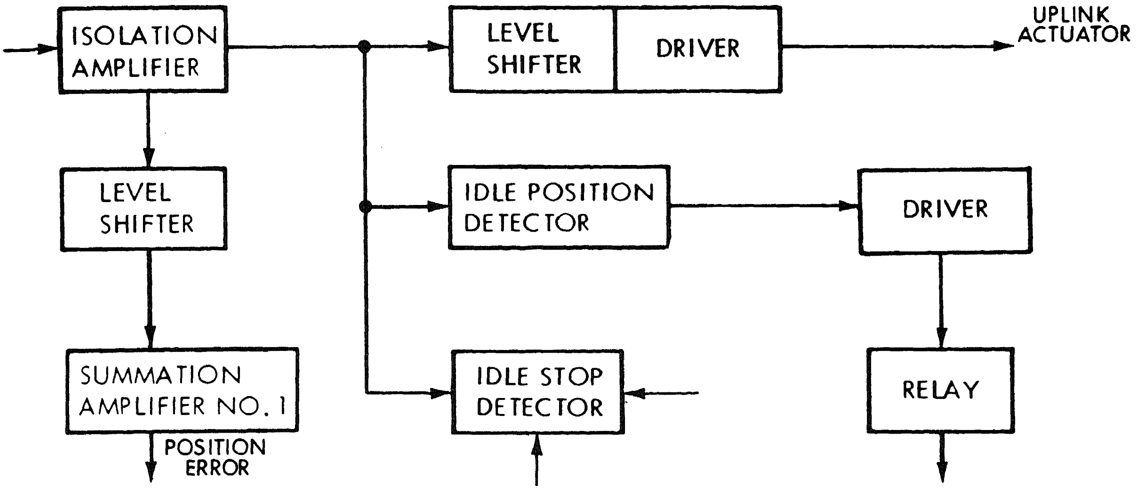

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Figure 7-5.—Potentiometer slider circuit.

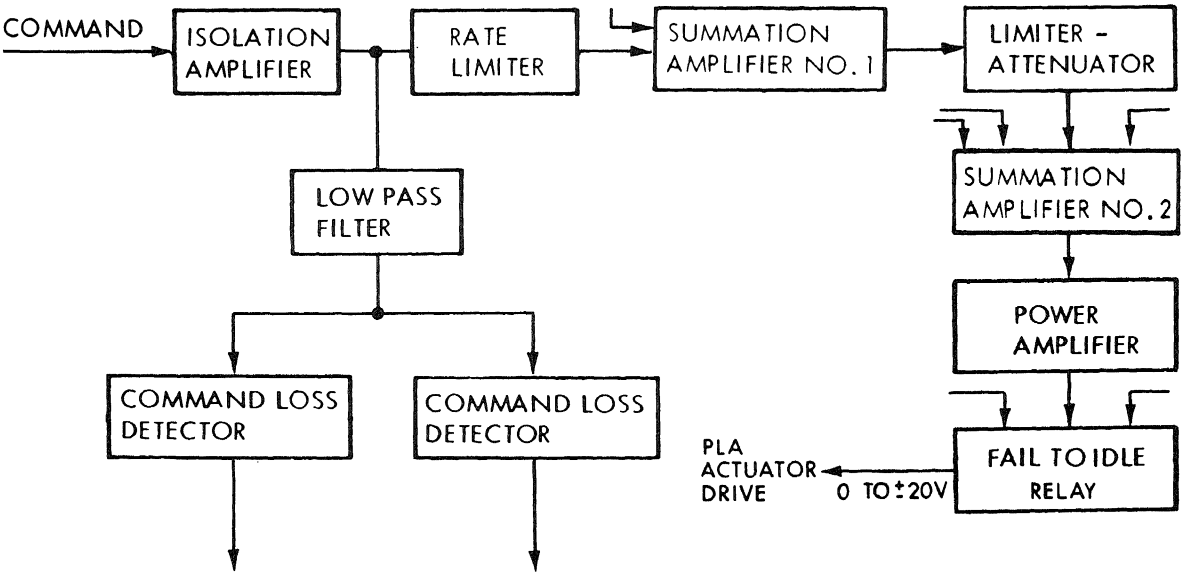

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Figure 7-6.—PLA command control

It limits it to preset increasing and decreasing rates.

The command signal (7) enters the FSEE and is sent to a unity gain isolation amplifier (8). This provides a high impedance load for the d.c. voltage of the command signal. The rate limiter (9) is used to limit the rate of change of command. The output of the rate limiter is sent to the summation amplifier (3). There it is summed with the position feedback signal. These two signals are of opposite polarity. The output of the amplifier is the position error (the difference in the position of the MFC lever and the command rate limit signal). This signal is applied to the limiter/attenuator (10). Under normal conditions it allows the signal to pass to the summation amplifier No. 2 (11) unchanged. The function of the limiter/attenuator will be discussed under the section on torque control. The output of summation amplifier No. 2 is sent to the power amplifier (12) in the power distribution assembly. It is then sent through the fail to idle relay (13) and used to drive the PLA actuator.

Tachometer Control

The tachometer (tach) control (figure 7-7) provides the rate of change feedback to control the response of the PLA actuator during MFC lever changes. This circuit is used to keep the lever from excessively overshooting the desired PLA position during changes. The tach control is also used during special cases for rate limiting during torque limiting. This is done when the command rate limiter is not used to control the rate of change of the PLA actuator.

The tach signal (14) is applied to two circuits on the A card. These are the tach amplifier (15) and the rate limit detector (16). The tach signal is a d.c. voltage signal proportional to the rate of change of the MFC lever. The signal is zero when there is no rate of change. The signal polarity will vary depending on the direction of movement of the PLA actuator. This signal is amplified in the tach amplifier (15) and sent to the summation amplifier No. 2 (11). Normally the signal is summed with the position error signal from the limiter-attenuator (10). The tach signal is subtracted from the position error signal during change of lever position. This reduces the signal output from the summation amplifier No. 2 (11). Since the signal to the PLA actuator is reduced, it tends to slow down. As the lever approaches the command position, the difference between the command signal and the position feedback is reduced. The tach signal then has greater control in slowing down the lever and reducing overshooting. When the command position is reached, the tach signal and the rate signal are both returned to zero.

The tach signal is also sent to the rate limit detector (16). There it is compared to a reference signal limit (V_{ref}). The V_{ref} represents the maximum limit for the rate of changes for the MFC lever. It does this in the increasing direction only. The output of the detector is the rate limit signal, when the input exceeds the reference limit. This rate limit signal is proportional to the amount the input exceeds V_{ref}.

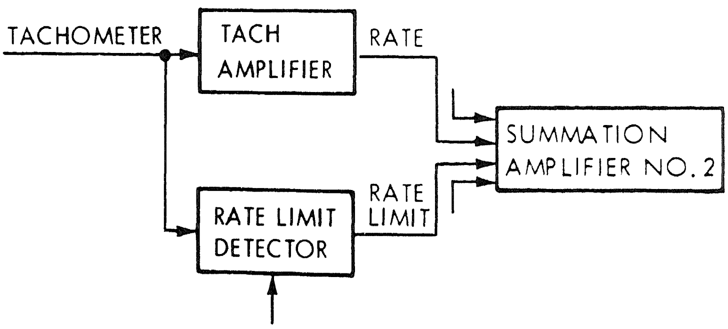

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Figure 7-7.—Tachometer feedback circuit.

The rate limit signal is sent to the summation amplifier No. 2 (11). There it is summed with the position signal and the rate signal. The rate limit signal is the same polarity (except for much greater amplitude) as the rate signal. This, then, tends to retard increases in the lever position. Because the rate limit signal is stronger, it has more effect in retarding the rate of change (only in increasing directions). It actually limits the rate of change to a point just a little higher than the limit set by V_{ref}.

The special case we discussed earlier involves limiting that may be specially required. This is when the PLA actuator is coming out of an overtorque condition and the MFC lever is returning to its command position. In this case, a large position error exists. This is because the command position and actual PLA position are out of line as a result of torque limiting. Because of this large error, the MFC lever would be driven to its new position at an excessive rate. The rate limiting circuit limits the actuator travel and allows a slower PLA response.

PLA Actuator Drive

The PLA actuator drive (figure 7-8) provides the power to drive the actuator motor. It also provides the fail to idle signal that drives the motor during FSEE malfunctions.

In normal operation, the output of the summation amplifier No. 2 (11) is amplified by the power amplifier (12) in the power distribution assembly. The output of this amplifier is sent through the fail to idle relay (13). This signal, in turn, is sent to the PLA actuator. A fail to idle signal is sent to the relay from either the fail or

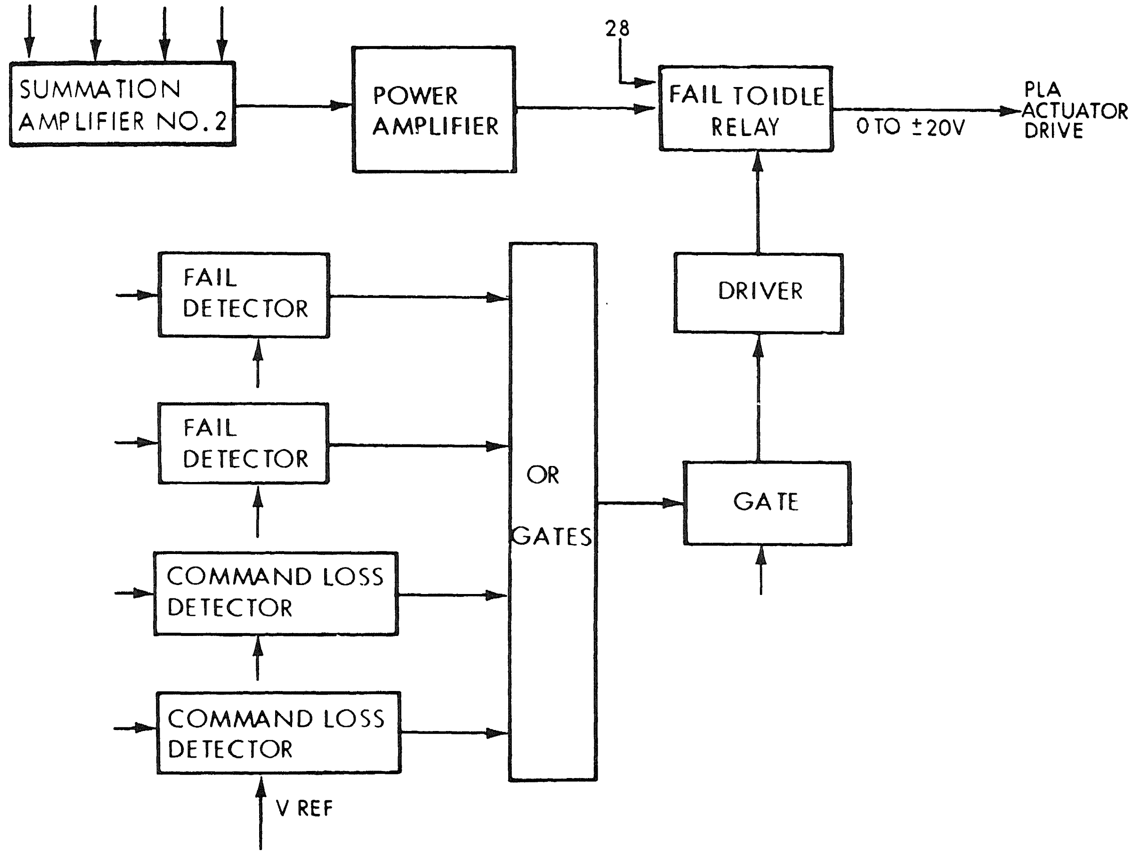

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Figure 7-8.—PLA drive and fail to idle circuit.

command loss detector (discussed later in this chapter). If this occurs, the amplifier output is disconnected by the gate (17); a 28-volt d.c. signal is inserted to drive the motor. The polarity of this signal is such that it drives the PLA to the idle stop.

Torque Control

Torque control (figure 7-9) provides torque limiting of the gas turbine. This is used when the engine torque exceeds the torque level set point. The torque control circuit may either restrict the advance or decrease the setting of the PLA.

The torque signal from the torque computer (19) (discussed later in this chapter) is amplified by the anticipation amplifier (20). This amplified signal is sent to the torque limit detector (21). There it is compared with either the full-power or split-plant set point from the gate (22). When the engine torque is above the torque limit set point, the detector outputs a signal proportional to the amount that the torque signal exceeds the limit (torque error). When this happens, the overtorque discrete generator (23) sends out a discrete signal. This signal indicates that an overtorque condition exists. This discrete signal is also sent to the limiter-attenuator (10) via an OR gate (24). This signal puts the limiter-attenuator into the mode where the position error is lessened and limited by the limiter-attenuator.

The torque error signal is also sent to the limits error selector (25). Applied to the selector are speed error and acceleration error signals. The selector outputs the largest of these three signals. This output is applied to the summation amplifier No. 2 (11) via a normally closed analog gate (26).

During an overtorque condition, the amplitude and polarity of the torque error signal are enough to overcome the other signals that input the summation amplifier No. 2. This then becomes the controlling signal used to drive the PLA. It sets the PLA at a lower setting limiting PT torque.

When the torque signal is below the torque limit set point, the output of the torque limit detector is zero. This allows the overtorque discrete generator to send out a below torque limit signal to the gate that controls the limiter-attenuator. This then allows the limiter-attenuator to pass through the position error signal without either limiting or attenuating.

The response of the torque limiting system to changes in torque is controlled by the torque anticipation amplifier. The output of this amplifier is approximately proportioned to steady state speed plus rate of torque change times a

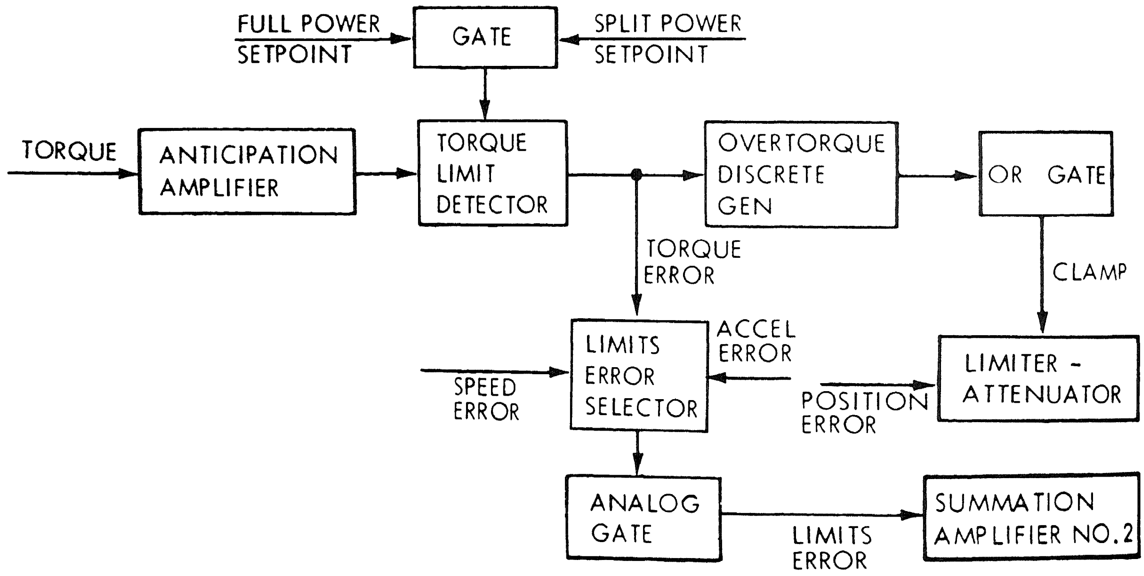

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Figure 7-9.—Torque control.

onstant. During steady state conditions, the mplifier has a gain of 2. During changes in orque, the amplifier anticipates these changes by dding an output signal component. This output proportional to the rate of change. During rapid ncrease in torque, the anticipation circuit causes ne torque limit set point to be reached earlier ithout the amplifier. The torque signal drives the IFC lever earlier in anticipation of an overtorque ondition. This reduces the possibility of overshooting the torque set point.

OVERTORQUE MONITORING.—The SEE outputs an overtorque condition uplink gnal to the propulsion consoles when the overtorque occurs. Figure 7-10 shows the overtorque iscrete signal circuit. The output of the torque limit detector (21) is converted to the overtorque discrete signal in the overtorque discrete generator (23). This output, in addition to the uses previously discussed, is sent to a gate (27). The gate selects either the test passed output or the overtorque output. The test passed output is only selected by the gate when the torque computer is put into a test. The selected gate output is sent to one of two drivers (28 or 29) to provide the uplink signals.

SET POINT MODE CONTROL.—The FSEE must select to which of the two set points to limit the engine torque. This is done by the set point mode control. The mode is selected by a discrete signal that tells the mode control whether one or two gas turbines are on line. Figure 7-11

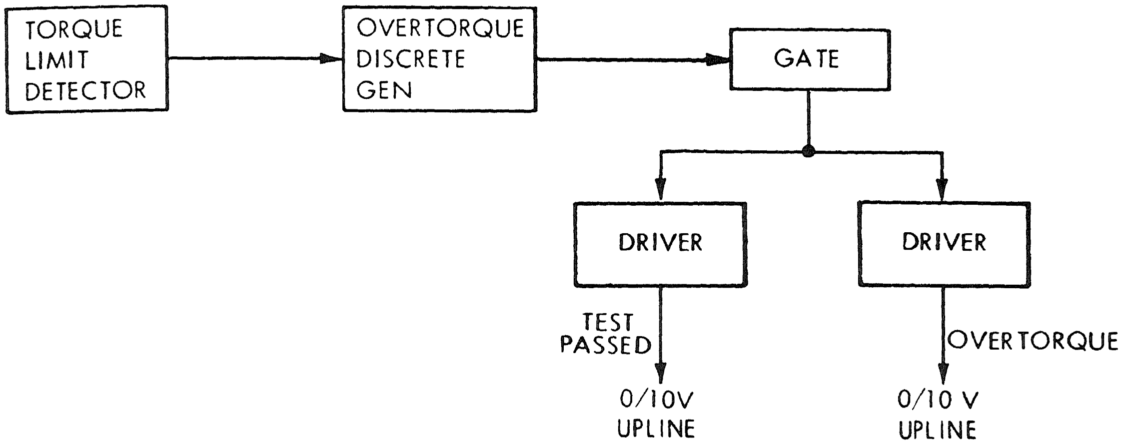

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Figure 7-10.—Overtorque discrete signal.

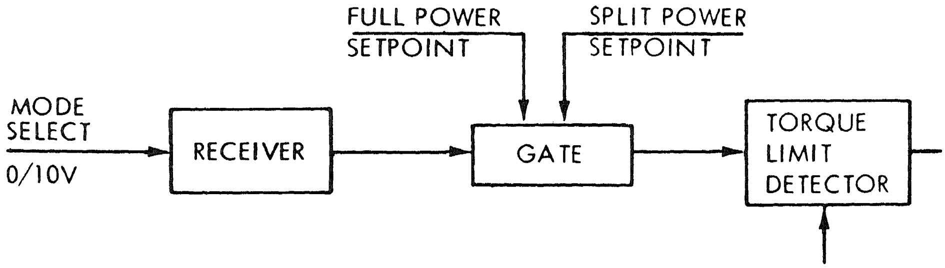

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Figure 7-11.—Torque setpoint detection.

shows the torque set point detection circuit. The input signal (30) is converted to a logic level signal in a receiver. The output of the receiver is used to control a logic gate (22). It selects either the split-plant (one GT) or full-power set points (both GTs) as the threshold for the torque limit detector (21). You can manually adjust each of the set point sources to calibrate the torque limiting level.

TORQUE COMPUTER TEST.—When the torque computer is tested, the torque loop is opened. Then a test torque signal is applied from the torque computer. This tests the torque computer and the torque limiting circuits. A discrete signal is generated and sent out to indicate the status of the test.

The torque testing circuit is shown in figure 7-12. The torque computer test signal (31) is conditioned to a standard logic level by a receiver (32). This signal performs three functions. First it is sent out to the torque computer (33) and causes a test torque signal to be generated. This test signal

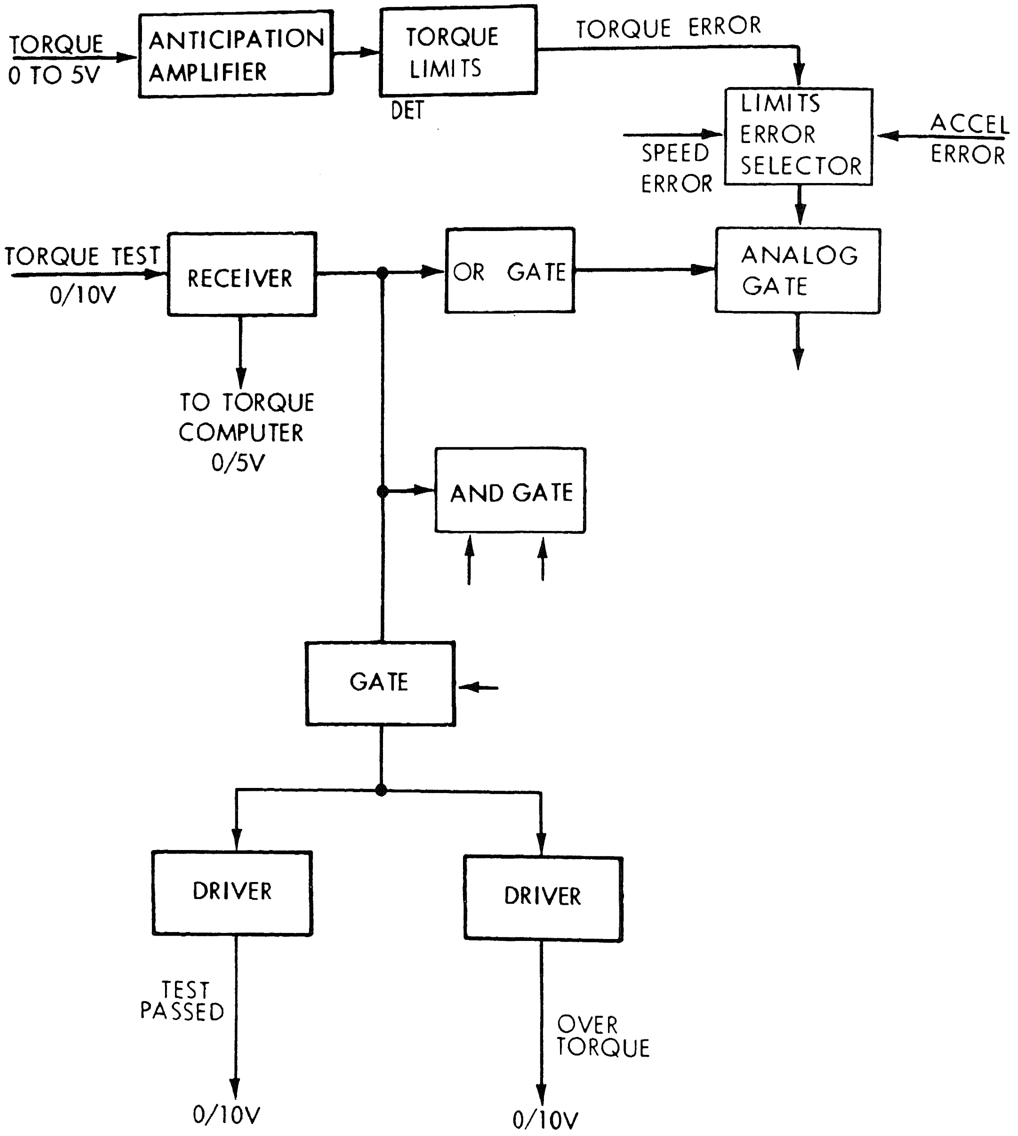

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Figure 7-12.—Torque testing.

; sent to the input of the torque limiting circuit 19) with a high enough amplitude to exceed the orque set point. Second, the output of the eceiver (32) is sent to the analog gate (26) at the utput of the limits error selector (25) via an OR ate (34). The analog gate is opened. It prevents ne torque error signal from affecting the MFC ever when a torque computer test is done. CAU-ION: Do not conduct the torque computer test n FSEE while the GTM is running. Third, the est signal also inhibits the overtorque driver (29) nd enables the test passed driver (28) via the gate 27). This causes the torque error signal to be assed uplink as test passed. If a circuit malfunc-on causes the test signal to be below the set point evel, the test passed output would be zero. The orque computer signal is also sent to a three-input ND gate and will be discussed in system fail nonitor.

peed Control

The speed control function of the FSEE limits ne PT speed if it attempts to exceed preset limit. igure 7-13 shows the speed control circuit. The T speed signal (35) is a voltage proportional to ne PT speed. (Refer to chapter 3 for an explana-on on the development of this signal.) The signal sent to a signal conditioner (36). Then it is sent o the speed anticipation amplifier (37) where it directed to the speed limit detector (38). In the peed limit detector, the signal is compared with preset speed limit signal.

The output of the anticipation amplifier (37) proportional to the steady state input speed gnal plus the rate of speed change times a onstant. Therefore, when engine speed is onstant, the anticipation amplifier acts as a ormal unity gain amplifier. When speed changes ccur, the output anticipates these changes by dding an output signal component. This output gnal is proportional to the rate of the speed hange. Thus, the preset limit can be exceeded arlier in time than would be the case without the nticipation amplifier. When the PT speed xceeds the limit, the speed limit detector outputs speed error signal. This speed error signal is pro-ortional to the amount that the speed input signal xceeds the limit. When the limit is exceeded, a gnal is sent to the speed limit discrete generator 39). The generator outputs a discrete signal that indicates speed limiting is in effect. This discrete signal is sent to the limiter-attenuator (10) via the OR gate (24). This puts the limiter-attenuator into the mode where the position error signal is either limited or attenuated. This is similar to torque control.

The speed error signal is also applied to the limits error selector (25) with the torque error and acceleration error signals. Again the output of the selector is the strongest of the three signals. This error output is sent through the analog gate (26) to summation amplifier No. 2 (11). When in speed limiting (as it was in torque limiting), the amplitude and polarity of the speed error signal will overcome the limited-attenuated position error signal. This then provides the output signal needed to drive the PLA actuator to the position where PT speed is limited to the preset limit. When PT speed is below the limit, the output of the speed limit detector is zero. In this case, no speed error is generated. This then allows the limiter-attenuator to pass the position error signal unchanged.

PT SPEED LIMITING DISCRETE SIGNAL.—The output of the speed limit discrete generator (39) is also sent uplink to the propulsion consoles. In this case, the signal output is a 10-volt d.c. signal produced by the driver (40). When this signal is produced, it indicates speed limiting is in effect.

SPEED LIMIT TEST.—The speed limiting circuitry has a test feature that allows testing of the speed limiting circuitry. When placed in test, a discrete 5-volt signal (41) is sent to an analog gate (42). This gate selects the test limit. This test limit is 75 percent of the normal speed limit. This allows checking of the PT speed limiting control at reduced PT speeds.

Acceleration Limiting

The acceleration limiting circuits are used only in the FSEEs installed on DD-963, DDG-993, and CG-47 class ships. The circuits are found on all the FSEE B cards, but they are not used on FFG-7 class ships. This is accomplished by adjusting the circuit out of the system.

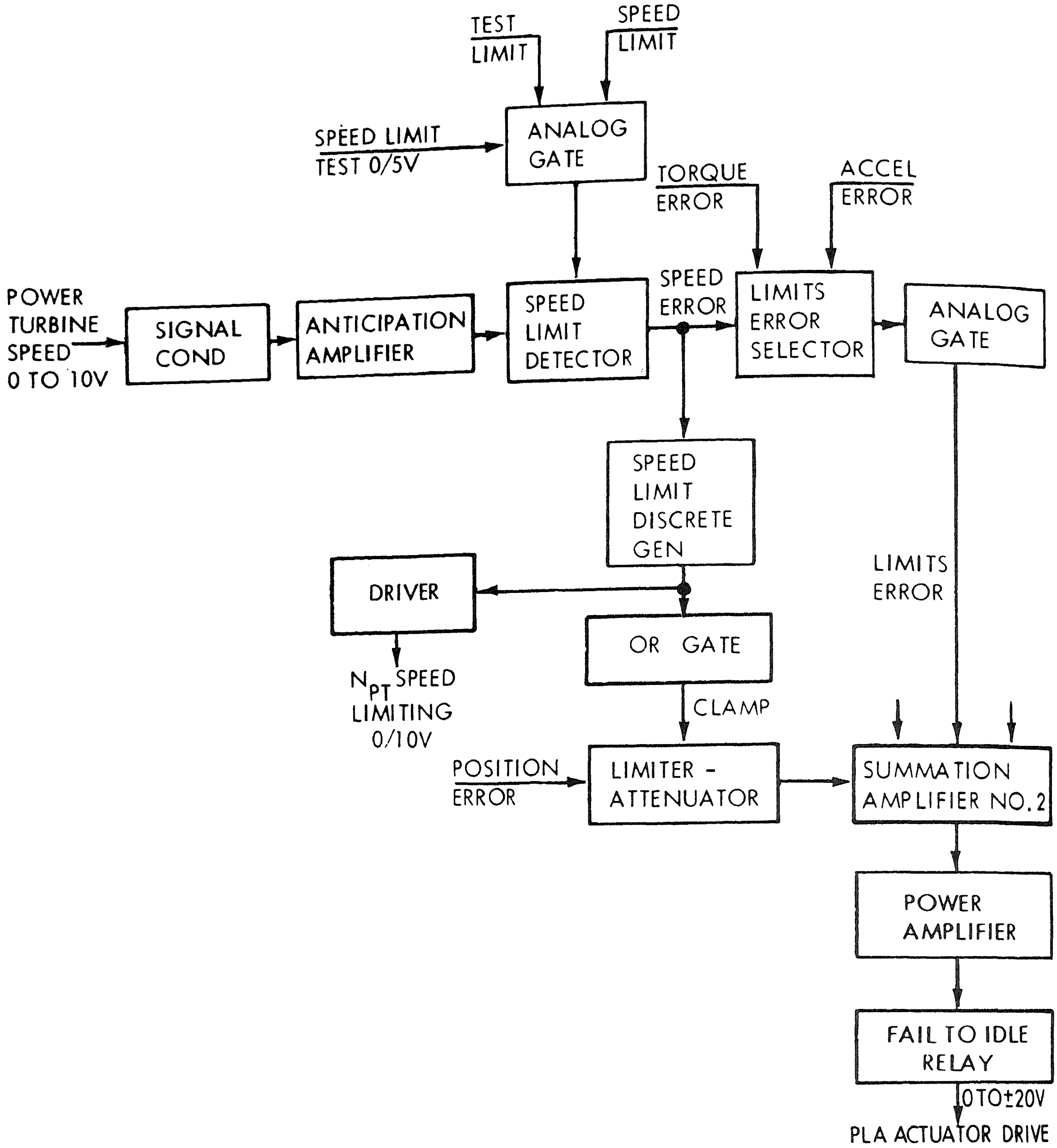

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Figure 7-13.—Speed control.

The acceleration control circuit (figure 7-14) provides limiting if the PT acceleration attempts to exceed a preset limit. The same PT speed signal used in speed control (35) is used in acceleration control. After being conditioned in the signal conditioner (36), the signal is sent to a differentiator (43). This responds only to changes in speed. The derivative of speed is acceleration. The differentiator calculates this derivative. It outputs a signal proportional to the rate of speed change and the time constant of the differentiator. This acceleration signal is compared in the acceleration limit

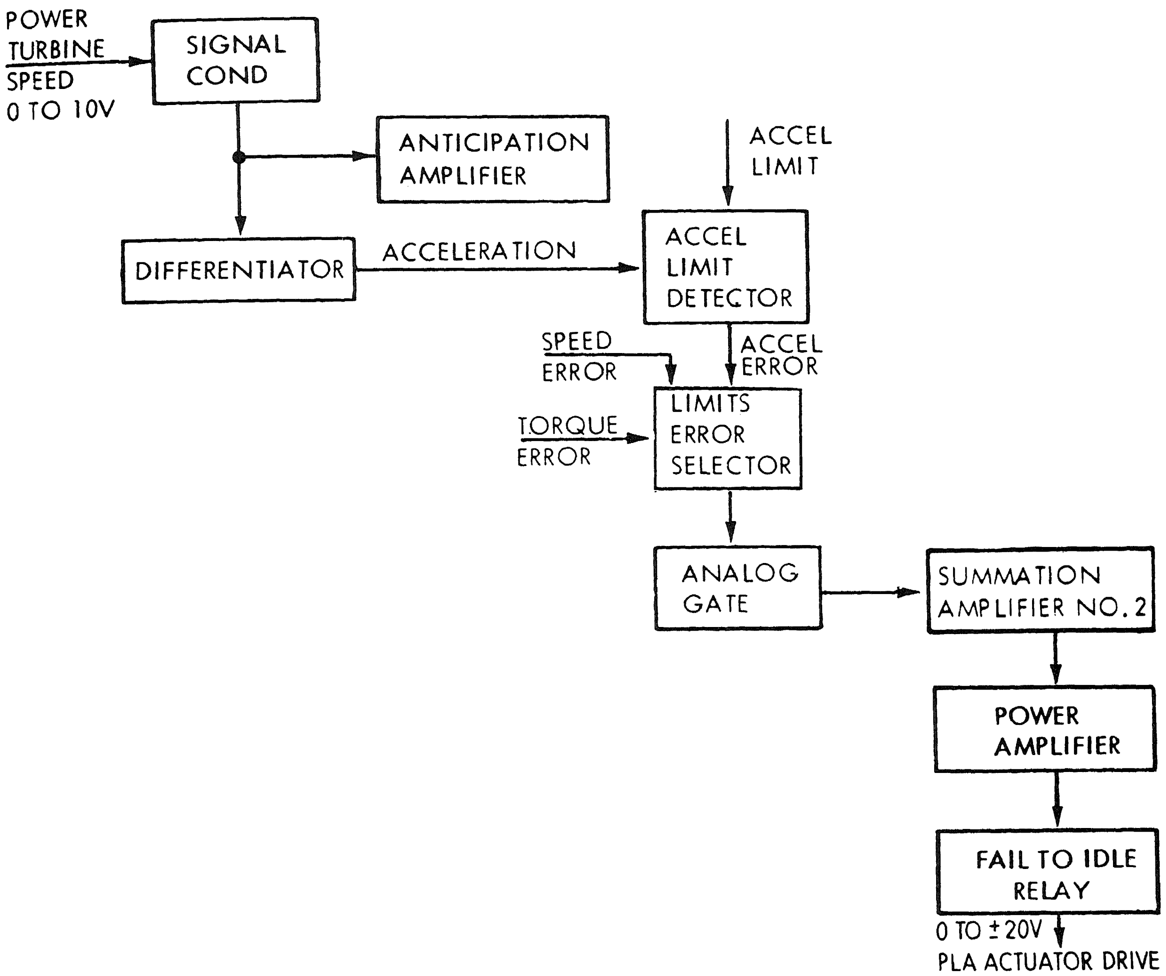

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Figure 7-14.—Acceleration control.

etector (44) against a preset limit. If the signal xceeds this limit, the detector will output a signal roportional to the amount the limit is exceeded. his output signal is called the acceleration error. his error signal is sent to the limits error elector. The selector then picks the strongest of e three error signals (speed, acceleration, and orque) and sends it to the analog gate. From the ate, the signal is sent to the summation amplifier Io. 2. At an amplitude determined by the PT cceleration and the time constant of the differen-ator, the amplifier provides an output to drive e MFC lever to a reduced power setting. This because of the polarity of the signal. The error signal controls the rate of change of the MFC lever. It adjusts fuel flow to the engine to reduce PT acceleration.

Command Loss

If the PLA command signal exceeds the maximum limit, or if it falls below the minimum limit, the command loss circuitry will drive the PLA to the idle stops. This is done by closing the fail to idle relay. The command loss signal also sends an uplink signal to the propulsion consoles. The signal shows the command loss condition.

The command loss circuit (figure 7-15) receives its signal from the output of the command unity gain isolation amplifier (8). It is sent through the low pass filter (45) which provides a short (185 millisecond) time delay. This allows short term command losses to be ignored. This signal then goes to two command loss detectors (46 and 47). One detector monitors the minimum limit; the other checks the maximum limit. These limits are set by the V_{ref}. If the command signal is in limits, then the output of both of the detectors is zero. If the command signal falls out of limit (either high or low), one of the detectors will output a discrete signal. This signal is then sent to an OR gate (48). The output of the OR gate goes through a gate (17) and driver (18) to the fail to idle relay (13). This relay applies a signal to the PLA actuator to drive the engine to idle.

The output of the OR gate is also applied to another OR gate (49) through a driver (50) to output the system fail uplink signal (51).

Fail Detection

A system malfunction is when the error signal to the PLA actuator exceeds a predetermined level for a predetermined time. When this malfunction occurs, a fail to idle signal is generated to send the MFC lever to the idle stop position.

In figure 7-16, the fail detection circuit is shown. The output of the summation amplifier No. 2 (11) (error signal) is sent to two failure detectors (53 and 54) via the low pass filter (52). This filter is used as a time delay. One failure detector is used to monitor positive signal error; the other monitors negative signal error. If this time delayed error signal exceeds the V_{ref}, one of the two detectors will send out a discrete signal. This signal is sent to an OR gate (48). The output of this gate (the same one used by the command loss circuit) is sent through a gate (17) and

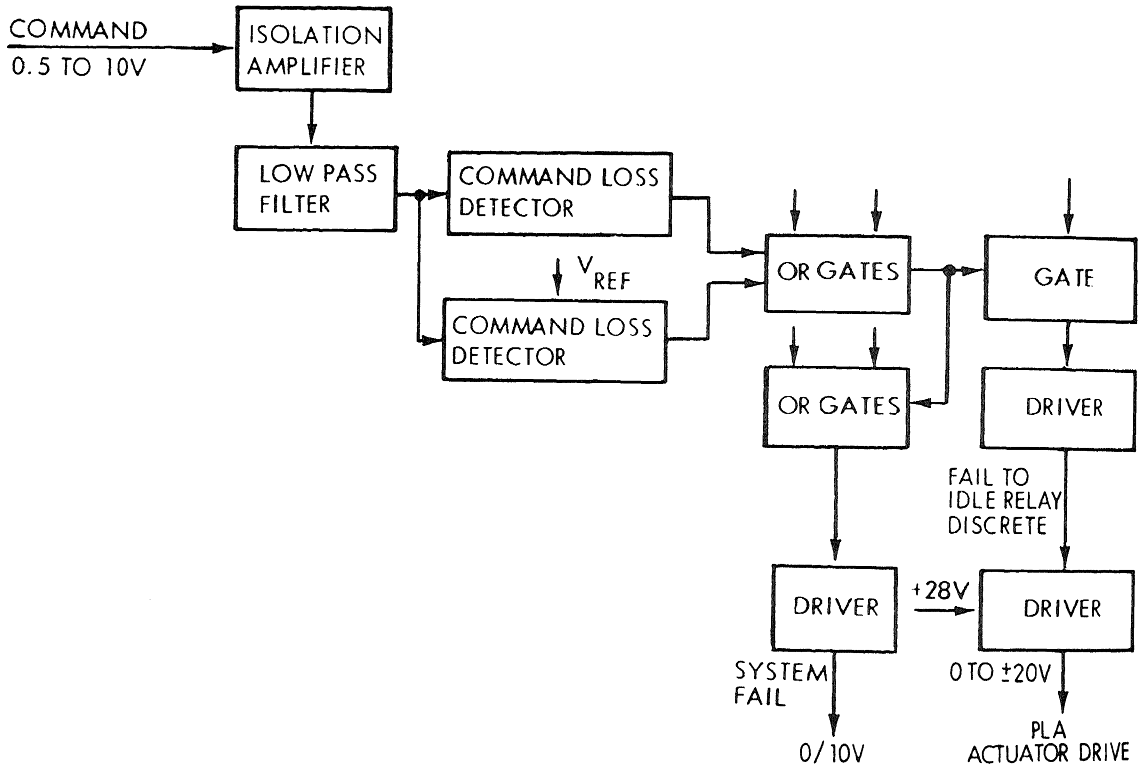

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Figure 7-15.—Command loss protection.

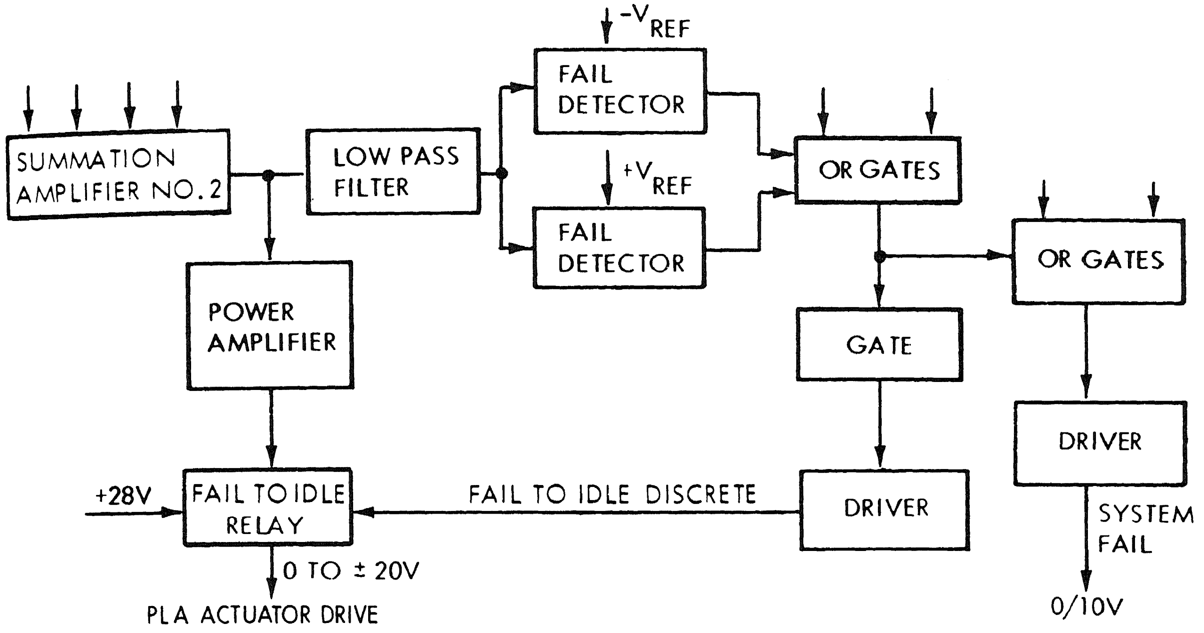

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Figure 7-16.—Fail detection.

driver (18). This causes the fail to idle relay to position the MFC lever to the idle stop. If the error signal drops below the level of both detectors, the circuit assumes the malfunction is corrected. It reconnects the PLA actuator back to the output of the power amplifier (12).

The output of the OR gate (48) is also applied to another OR gate (49) and driver (50). This then outputs the system fail uplink signal (51).

System Fail Monitor

Three conditions will cause the system fail discrete signal to be sent uplink. First, the signal may be generated when the fail to idle relay is driving the PLA actuator to idle. This is because of the command loss or fail detection circuits mentioned before. Second, the signal may be generated when the MFC lever is at the mechanical stop. Thirdly, the signal may be generated when the MFC lever is in the idle position and an overtorque discrete signal exists.

The system fail monitor circuit is shown in figure 7-17. Three inputs are sent to the system fail OR gate to generate the uplink signal. Any one of the three inputs will trigger an output. The first input comes from the OR gate (48) that receives signals from the fail detectors and command loss detectors. The second input comes from the idle stop detector (55). The idle stop detector will output a discrete signal when the PLA actuator position (from the potentiometer slider in the actuator) is below the idle set point. This set point is the V_{ref} applied to the idle stop detector. The third input comes from the three-input AND gate (56). These AND gate inputs come from the idle position detector (5), the overtorque discrete generator (23), and the torque test signal (31) from the receiver (32). This AND gate outputs a signal only when the PLA is at idle, an overtorque condition exists, and the torque computer is not in the test mode. The AND gate signal will then trigger the OR gate (49) to output a system fail from the driver (50).

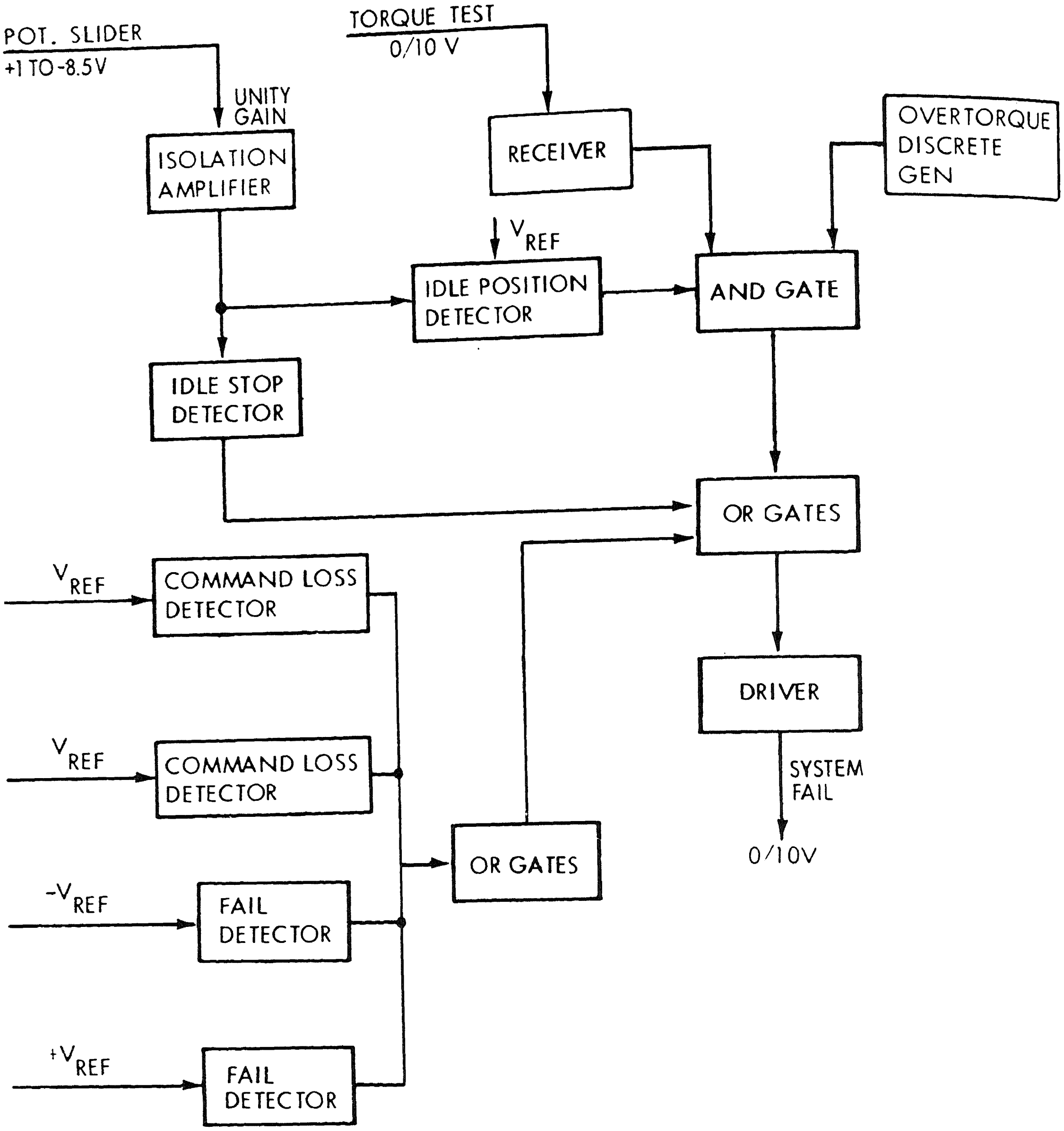

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Figure 7-17.—System fail monitor.

Battle Override/Reset Control

Battle override (figure 7-18) inhibits all torque, speed and acceleration limiting, and the fail to idle protection.

The battle override signal (57) is sent to the FSEE from the propulsion console. This signal is converted to a logic level by a receiver (58). The output of the receiver is sent to two gates to perform the battle override functions. The first gate (34) outputs a signal to open the normally closed analog gate (26). This prevents the torque, speed, or acceleration error from being sent to summation amplifier No. 2 (11). The other gate (17)

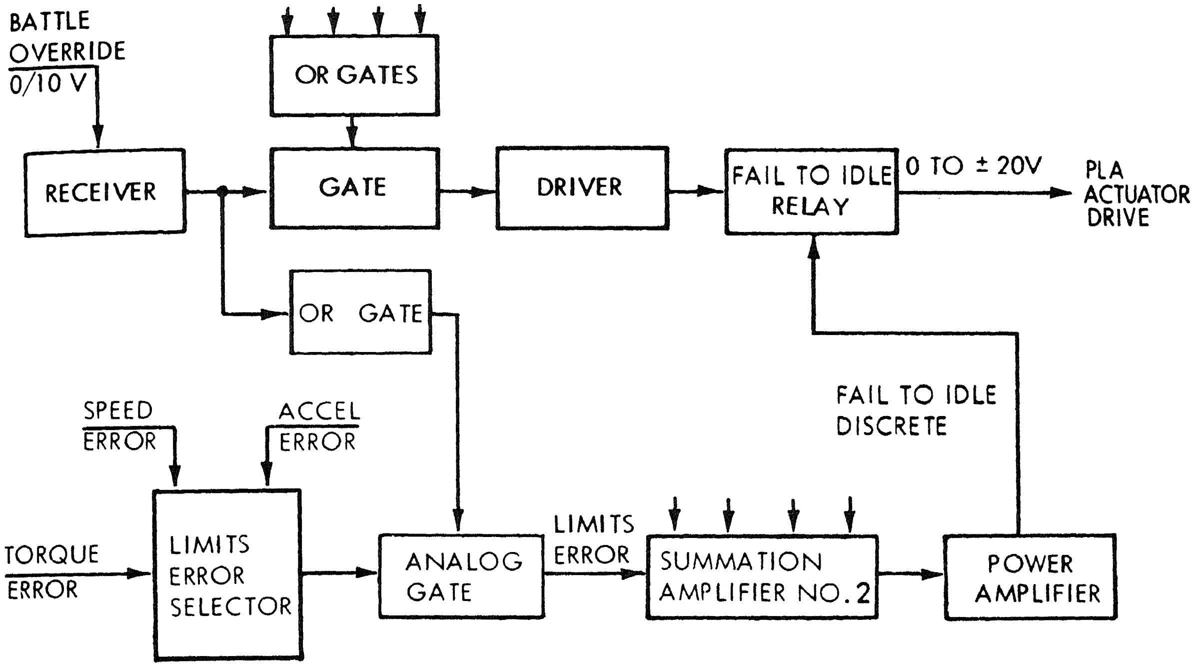

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Figure 7-18.—Battle override.

ffected by battle override controls the fail to idle elay. When the battle override signal is applied, his normally closed gate is opened. This prevents he output of the OR gate (48) from triggering he fail to idle relay and sending a signal to posi-on the MFC lever to idle.

Because battle override disables many control eatures of the FSEE, its use is carefully con-rolled. Normally, only the commanding officer nay give permission to use the battle override eature.

'T OVERSPEED ELECTRONICS

The FSEE contains two identical circuit oards per engine used for overspeed protection. 'hese are the D cards. Each card receives its signal rom its own speed pickup and controls both fuel alves. (Recall, there are two fuel solenoid valves iped in series, but wired in parallel.) This allows or two independent speed channels and two ndependent overspeed trips.

The overspeed control circuits function to shut down the engine if a PT overspeed, PT underspeed, or a loss of control power to the control circuit occurs. When any of these conditions exist, the circuit will de-energize the engine fuel valves. This will shut off the engine fuel supply. The circuit is a latching type. This prevents the fuel valves from opening when the condition clears. You must use an external reset to reset this circuit.

Figure 7-19 is a block diagram of the PT overspeed switch. It shows the circuits of two D cards. The speed pickups of the PT (covered in chapter 3) send a frequency signal to the D card proportional to the PT speed. This signal (one from each pickup) enters the card and goes to a signal conditioner (1). The signal conditioner and frequency to voltage converter (2) changes the frequency level to a voltage level that corresponds to it. This voltage is then compared to two preset limits in the limit 1 (3) and limit 2 (4) comparators. The limit 1 comparator is used to detect loss of speed signals. This limit is adjustable over a range

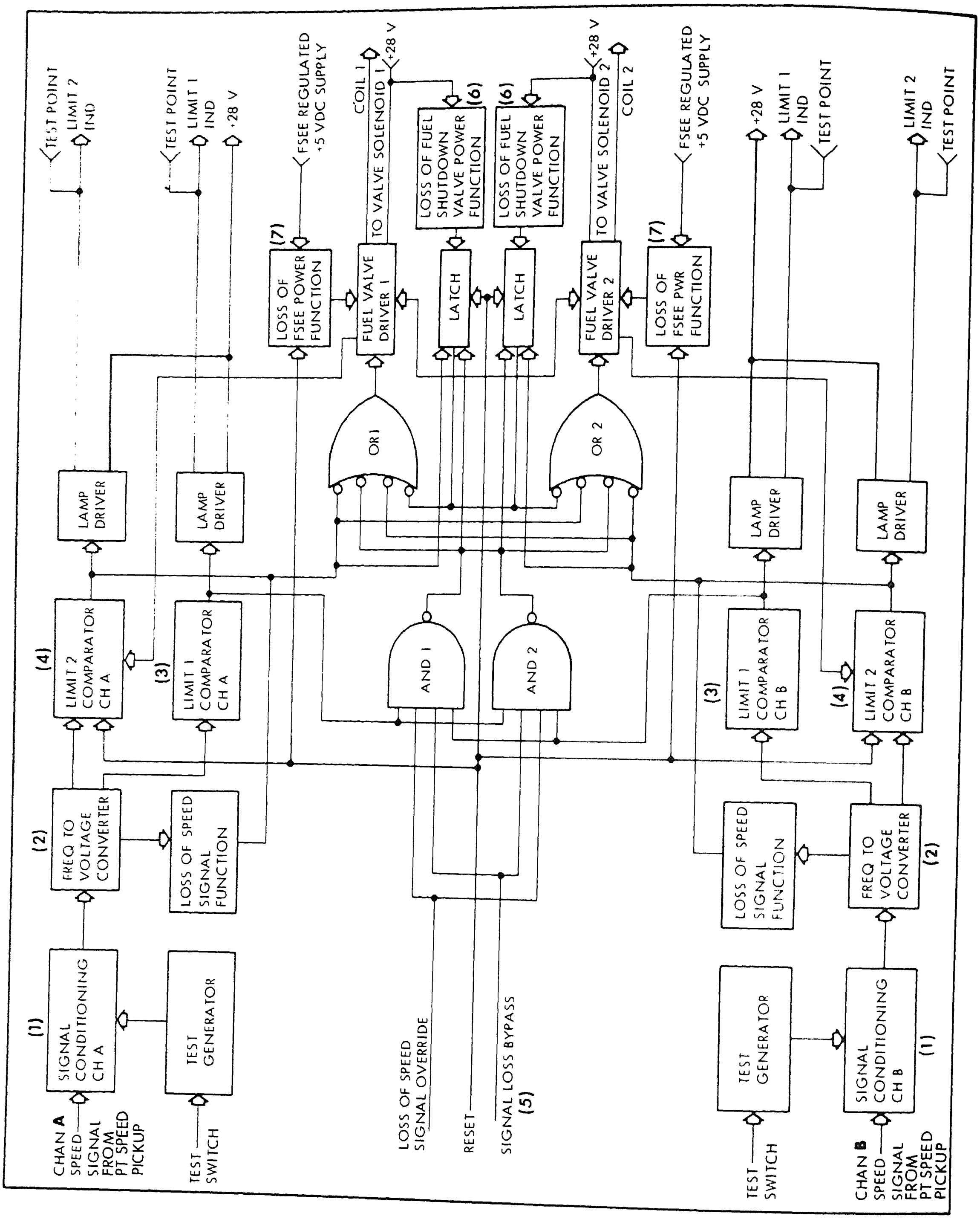

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Figure 7-19.—Power turbine overspeed switch block diagram showing the circuits of two D cards.

f 100 to 725 rpm. To generate the signal needed
› close the fuel valves, both channels A and B
ıust detect a speed lower than the preset limit.
his set point is normally near 100 rpm PT speed.
he limit 2 detector is used to detect PT
verspeeds. This limit is adjustable over a range
f 3000 to 4000 rpm. It is normally set at
960 ± 40 rpm. If either channel detects an
verspeed condition, a signal will be generated to
ıut the fuel valves.

Because during start-up the PT speed is below
ıe limit of the No. 1 comparator, some method
ıust be used to allow the fuel valves to remain
pen. This is done by an input from the PLA elec-
onics known as signal loss bypass (5). This signal
present when the PLA actuator is between idle
nd a nominal 30 degrees. When the PLA is
dvanced above this limit, the PT speed must be
bove 100 rpm. If the engine is not above 100
pm, it will shut down.

Each channel has a test generator used to
pply a test signal to the channel. The FSEE
as pushbuttons used to test the overspeed
ips. When depressed, these pushbuttons acti-
ate the test generator which simulates an
verspeed condition. This will activate the over-
peed trip alarm and shut the fuel valves. You
ıould only perform this test on nonrunning
ngines.

The D cards also have voltage detectors (6) and (7). The first detectors (6) monitor the voltage going to the fuel valves. If this voltage drops below 20 volts d.c. for 10 milliseconds (msec), the fuel valves close and are latched off. Also, loss of FSEE 5-volt d.c. power will signal the fuel valves to close and latch them until reset. CAUTION: Never depress the PT overspeed reset pushbutton on the propulsion consoles after an underspeed, overspeed, or loss of voltage until the engine comes to a complete stop. Doing so could cause the fuel valves to reopen and enable a restart of the engine. This restart may cause severe damage to the GT.

SIGNAL CONDITIONER

Each engine has a signal conditioner card (E card) used to condition speed, pressure, and temperature sensor signals. (Each FSEE, therefore, has two E cards.)

Five analog signals are sent to the signal conditioner (figure 7-20). These are P_{t2}, $P_{t5.4}$, T_2, and two N_{pt} speed signals (one from each pickup). The conditioner also processes one internal signal. Four of the signals are sent to the torque computer. Five signals are buffered and sent uplink to the propulsion console. The two pressure signals, P_{t2} and $P_{t5.4}$, are received from

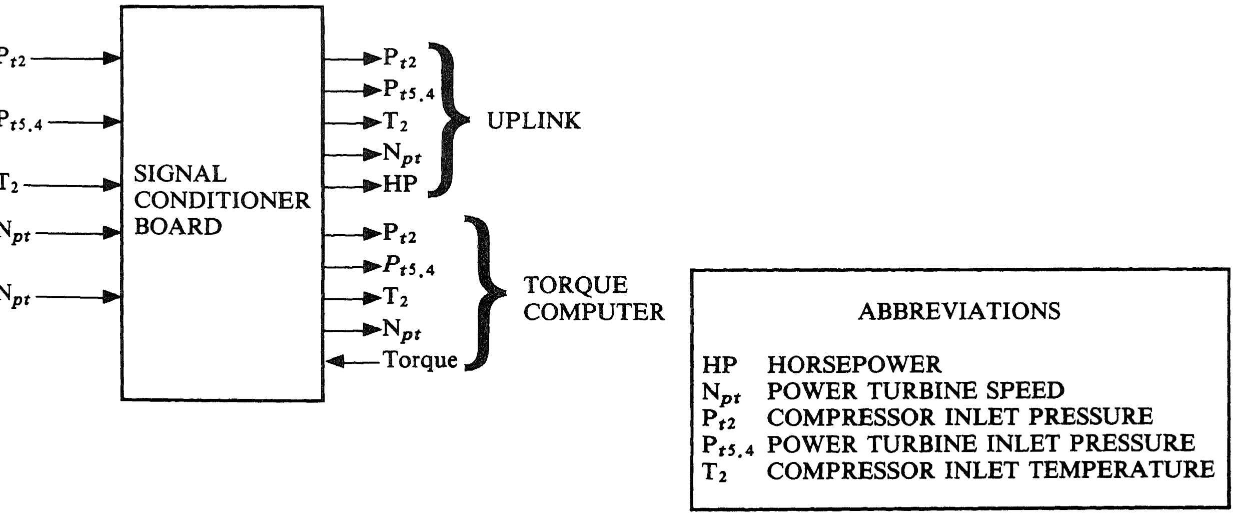

Figure 7-20.—Signal conditioner inputs and outputs.

transducers as a 4- to 20-mA signal. These are converted to 0 to + 5 volts d.c. for use in the torque computer. They are also sent to a buffer amplifier with a two-to-one gain to output a 0- to 10-volt d.c. uplink. The one temperature signal, T_2, is inputted to the signal conditioner as a resistance change from an RTD. This signal is also converted to 0 to 5 volts d.c. for the torque computer. It is converted to 0 to 10 volts d.c. for uplink. A voltage regulator is used to convert a -15 volt d.c. bus supply to a precision -12 volt d.c. for use in the temperature bridge and speed signal conditioner circuits. The speed inputs from both PT speed pickups are sent to the conditioner as frequency signals proportional to the PT speed. Switching is provided to switch from the primary input to the alternate input in case of primary failure. Two multiplying tachometers are used to multiply this frequency by a voltage level. In the first tachometer, the reference voltage is fixed. The output is directly proportional to the PT speed. This output is sent to the torque computer and also uplink. The second tachometer uses a torque proportional voltage for comparison. This voltage, when multiplied by PT speed, produces a voltage proportional to the horsepower developed by the engine. This voltage is then sent uplink for use in the propulsion consoles.

TORQUE COMPUTER

Seven of the circuit cards per engine make up the torque computer. These are:

Card Designation	Name
F	Input/Output No. 1
H	Control
J	Arithmetic
K	Address Control
L	Memory
N	Input/Output No. 2
P	Sub Command

The torque computer is a special purpose computer used to calculate engine torque. A block diagram of the torque computer is shown in figure 7-21. Four analog inputs are used by the computer for its calculation. These are T_2, P_{t2}, $P_{t5.4}$, and N_{pt}. They are supplied to the computer from the signal conditioner and inputted on the F card (input/output No. 1). These four inputs are filtered and sent to the analog multiplexer (2). The output of this multiplexer is sent to the N card (input/output No. 2) to an analog to digital (A/D) converter (3). There the signals are converted from analog to digital. The four digitized signals are sent (along with two other digital signals, bleed air, and test) to a digital multiplexer section (5). They are forwarded to the main data bus (6). The output of the multiplexer section is then sent to the memory (7) for storage. The memory has both Read Only Memory (ROM) and Random Access Memory (RAM). ROMs are used to store two program sections and a data table. Two ROMs are used to store the sequence of instruction needed to solve the torque computations. The third ROM, storing the data table, supplies information to another part of the computer. That part of the computer calculates torque as a function of temperature.

The RAM is used to temporarily store data used in the torque calculations. The input data, after being digitized, is stored in the RAM before making the torque calculations.

The sub command board (P card) receives the program instructions from the memory (the ROMs). This section then decodes these instructions and provides the output control lines to control the system. The control lines are used to output 35 exclusive lines of control. These control lines execute control of the arithmetic functions as well as the inputs and outputs of the computer.

The arithmetic section (J board) has three registers—the A, B, and C (8, 9, and 10). The A register is also known as the accumulator register. It is used to store the results of the arithmetic functions. The B and C registers are used to store the numbers being used in the operation. The

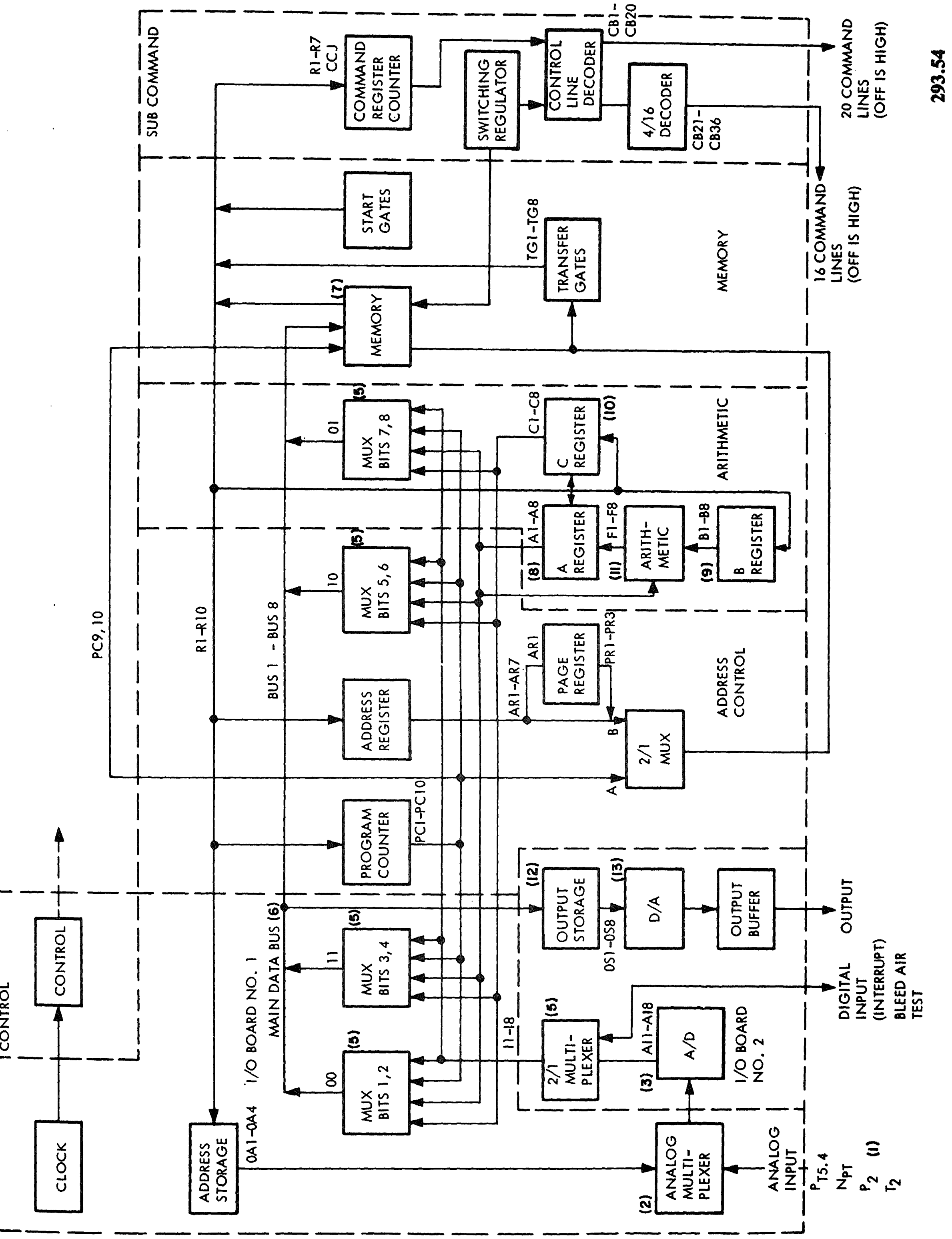

Figure 7-21.—Torque computer block diagram.

arithmetic board receives the control signals from the sub command. It uses these signals to execute, in the proper sequence, the arithmetic calculations used to compute torque. The arithmetic logic unit (11) performs the actual operations such as adding, subtracting, and comparing. The result of these computations, when properly scaled, becomes the output torque value. The digital output of the A register is then sent back to the multiplexer section (5) to the main data bus (6). Then the signal is sent to the output storage register (12). There it is converted to an analog signal in the D/A converter (13). The analog output is then buffered and sent out of the computer to the components that use this torque signal.

The torque computer is constantly resetting and recalculating torque. It operates at a much faster rate than the propulsion system can react. For a more detailed explanation of the torque computer, refer to the reference at the end of this chapter, *Propulsion Gas Turbine Module*, LM2500, Volume 1, Part 1.

– 12 VOLT D.C. AND – 15 VOLT D.C. POWER CONVERTER

One circuit card found only in FFG-7 FSEEs but not in DD, DDG, or CG FSEEs is the T card. This card is used as an independent power supply for the B channel of the PT overspeed card (D card).

It provides uninterrupted overspeed protection if a failure of the – 12 volt d.c. regulated voltage from the signal conditioner card occurs.

OVERSPEED INDICATOR PULL-UP RESISTOR

The overspeed pull-up resistor card (M card) is used only on the DD-963, DDG-993, and CG-47 class ships. Only one M card is used in these FSEEs and serves both GTs. This card has eight 2000-ohm, 1-watt resistors, divided into four groups of two each. These resistors are used as pull-ups for the PT overspeed switch indicator circuits.

FFG-7 START/STOP SEQUENCER

The start/stop sequencer is installed in the FSEE on FFG-7 class ships. It provides signal conditioning, monitoring, and logic circuits required for safe GT starting and stopping. Nine circuit cards are used for this feature. Three cards (the X, Y, and Z cards) are signal conditioners. Four of the cards are logic cards (the AB, AD, AE, and AC cards). The other two cards are a transmitter card (AA) and a thermocouple amplifier card (V).

The start/stop sequencer provides the following functions.

- Signal conditioning of gas turbine parameters
- Monitoring of vital parameters
- Sensing out-of-limits instrumentation signals
- Signal conditioning output status signals
- Initiating automatic control signals
- Receiving and processing operator commands

SEQUENCE MODES

The start sequencer has three sequence modes available. These modes are auto, manual, and auxiliary (or test) mode.

In the auto mode, when commanded by a signal from the propulsion control console (PCC), an automatic start-up of the GT can be performed. This auto start sequence using a programmed time sequence monitors and controls the engine starting. Parameters monitored include N_{GG}, $T_{5.4}$, fuel manifold pressure, and lube oil supply pressure. If these parameters are not within limit during start-up, the sequencer will initiate an immediate automatic shutdown.

In the manual mode, an operator is required to initiate the starter on, fuel on, and ignition on

mmands. When the sequencer receives a manual art command, it provides the time sequence and gine parameters for the operator's information. ne conditions that would cause shutdowns in the tomatic mode provide only an alarm in the anual mode.

The auxiliary mode (or test mode) is used to st the engine start components. When in this ode, the fuel and ignition cannot be activated the same time.

In the auxiliary mode, the operator can check e fuel system without causing a start of the gine. This is done by manually motoring an gine, and at 1200 rpm, energizing the fuel lves. Then the operator checks the operation the fuel system components. This is done by onitoring fuel supply temperature, pressure, el flow, and fuel manifold pressure. In this ay, operation of the fuel pump, main fuel ntrol, and fuel shutoff valves are checked. ne shutdown valves normally are de-energized the same time to shut down the engine. A el valve test mode allows you to test the lves alone to ensure proper operation of e valves. You can only do this test when LA is at idle. (Also, you can perform a st of the ignition system independent of the el system tests.) The ignition test will cause the niters to be on as long as the igniter pushbutton depressed.

UTO START SEQUENCE

Please follow figure 7-22 as we discuss the auto art sequence mode of the FSEE.

Several permissives are required for starting e GTM. These permissives require PLA to be idle, GG speed to be below 3500 rpm, and rious shipboard systems to be aligned. When e command to start is sent to the FSEE and the rameters are met, the sequencer will start the gic controlled start sequence.

The first command asks if the auto mode is lected. If not, no further action will occur. ut if it has been selected, the command is sent see if the auto start signal has been sent. If not, no further action will occur. But if the signal has been sent, the circuit will reset all alarms and the PT overspeed switch (reset to the D cards). After these alarms are reset, several commands are sent out. These commands open the starter air valve, energize three timers, and enable the ice detector circuit to function. The three timers are

- failure to start (achieves 1200 rpm in less than 20 seconds),
- failure to idle (achieves 4500 rpm in less than 90 seconds), and
- lube oil pressure delay (delays low lube oil pressure shutdown 45 seconds).

As the engine starts to rotate, the circuit will begin checking to see if it has reached 1200 rpm. If it has, the sequencer will energize the igniters. It will open the fuel valves and start a 40-second fail to lightoff timer. If 1200 rpm is not reached, it will (1) send out an alarm signal, (2) close the starter air valve, (3) de-energize the ice detector, and (4) wait for reset or restart.

After the engine's fuel system and igniters are enabled, the engine should start combustion. The circuit will start checking if the engine has reached above 400 °F $T_{5.4}$ within the 40-second fail to lightoff timer duration. (If it has, the circuit checks the fuel manifold pressure to see if it is above 50 psig.) If so, the engine timer and start counter are energized. Also, the sequencer begins checking rpm to see if it is above 4500 rpm. If 40 seconds elapse and $T_{5.4}$ is below 400 °F, (1) the fuel valves close, (2) the igniters are turned off, (3) a fail to lightoff alarm is generated, and (4) a 60-second monitoring delay is activated. This motoring delay allows the starter to continue rotating the engine. This is to purge out any fuel buildup for 60 seconds. After 60 seconds, the starter valve is shut, the ice detector de-energized, and the circuit waits to be reset or be restarted.

After combustion occurs, the circuit is waiting for 4500 rpm within 90 seconds. When 4500 rpm is reached (1) the igniters are turned off, (2) the

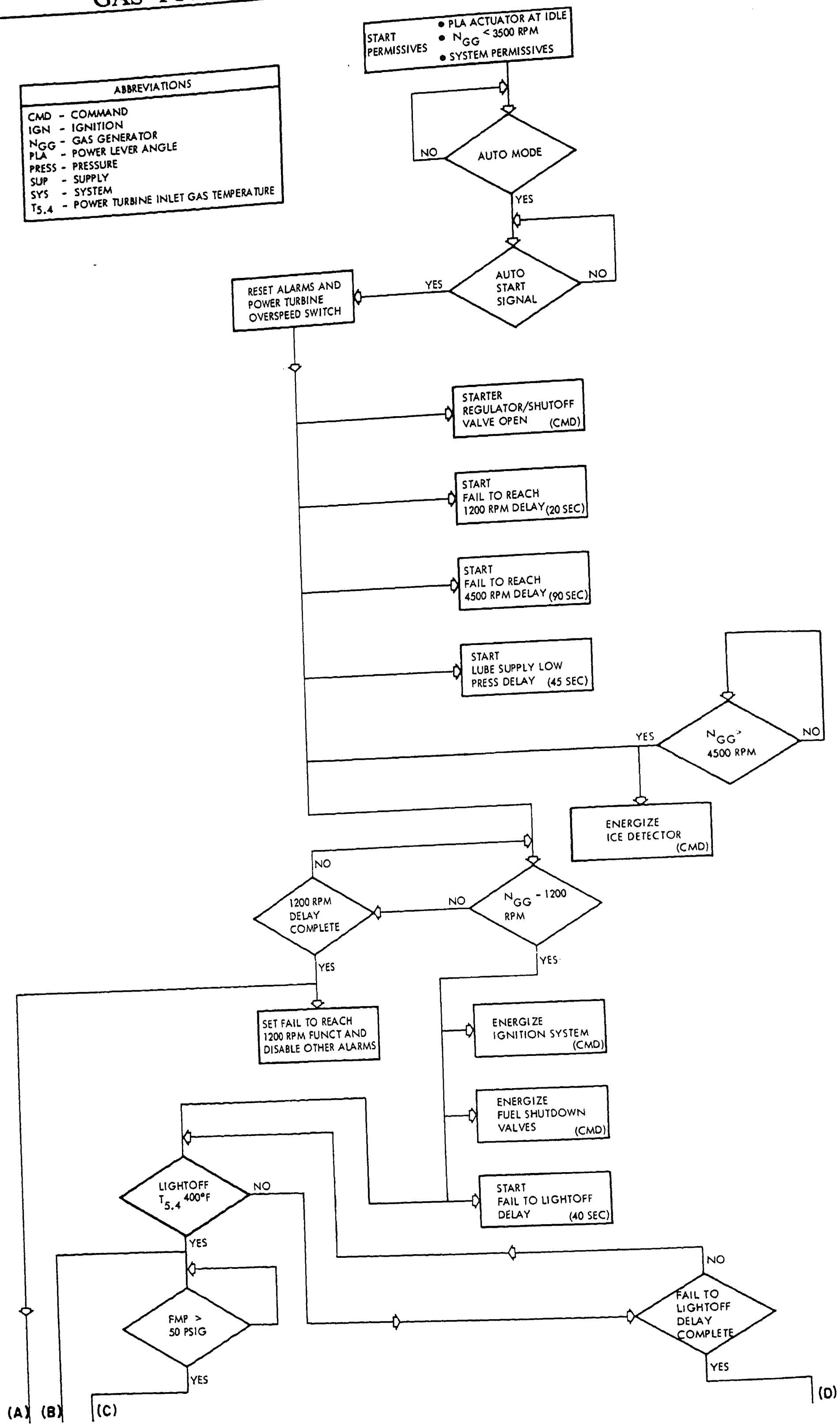

Figure 7-22.—Auto start sequence.

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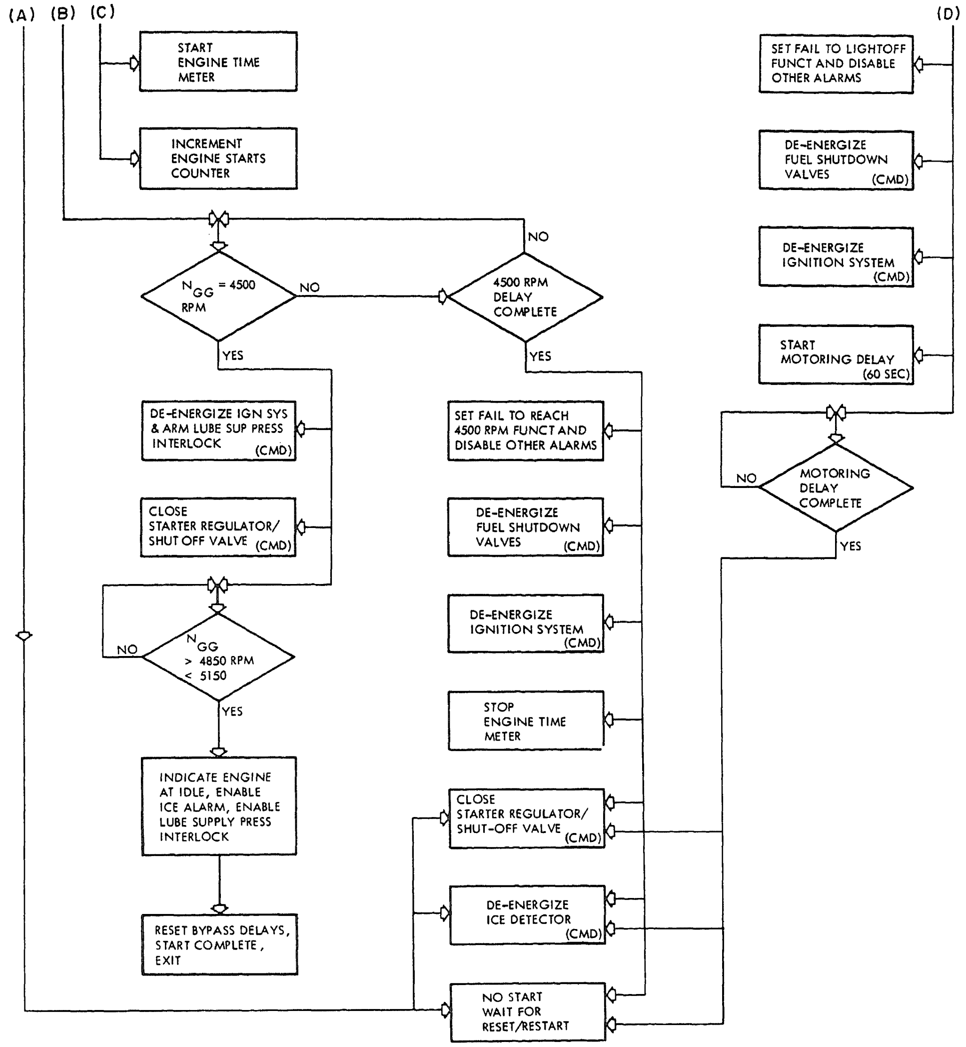

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Figure 7-22.—Auto start sequence—Continued.

ow lube oil pressure circuit is armed, (3) the tarter valve is closed, and (4) the circuit starts hecking if engine speed is between 4850 to 5150 pm. When this is achieved, the idle indication ccurs. Then the ice alarm and the lube oil upply pressure interlock are enabled. The start s then complete. If the engine does not reach 500 rpm in 90 seconds, the following occurs: 1) the fail to reach 4500 alarm sounds, (2) the uel valves are shut, (3) the igniters are de-nergized, (4) the engine time meter is stopped, (5) the start air valve is closed, (6) the ice detector is de-energized, and (7) the circuit waits to be reset and restarted.

MANUAL AND AUXILIARY SEQUENCES

Very little logic is involved in the manual or auxiliary sequence mode. In these modes, the protection of the engine is left more in the operator's

control. Figure 7-23 is a flow diagram of the manual and auxiliary control modes.

In the manual mode the operator depresses the starter air pushbutton, following the EOSS, to start the engine turning. If engine speed is above 4500 rpm, no command will be sent to the starter air valve. This is also used to turn off start air when the engine reaches this speed. After observing that the engine speed is above 1200 rpm, the operator can turn on the igniters and open the engine fuel valve. (NOTE: The starter air and igniter pushbuttons on the LOP are momentary-type pushbuttons. You must continue depressing them to keep the command active.) This action should cause combustion to occur. The operator, following the EOSS, has to release the igniter pushbutton to turn the igniters off. Even if the starter air pushbutton is still depressed, the starter will cut out at 4500 rpm.

The auxiliary mode logic is also very simple. It allows the operator to use starter air any time the engine is below 4500 rpm. This is regardless of fuel or igniter status. You may only open the fuel valves if the igniters are off. Likewise, you may only energize the igniters when the fuel valves are closed.

START/STOP CIRCUITRY

As we mentioned earlier, the start/stop sequencer uses nine circuit cards. We will discuss their functions in the following section.

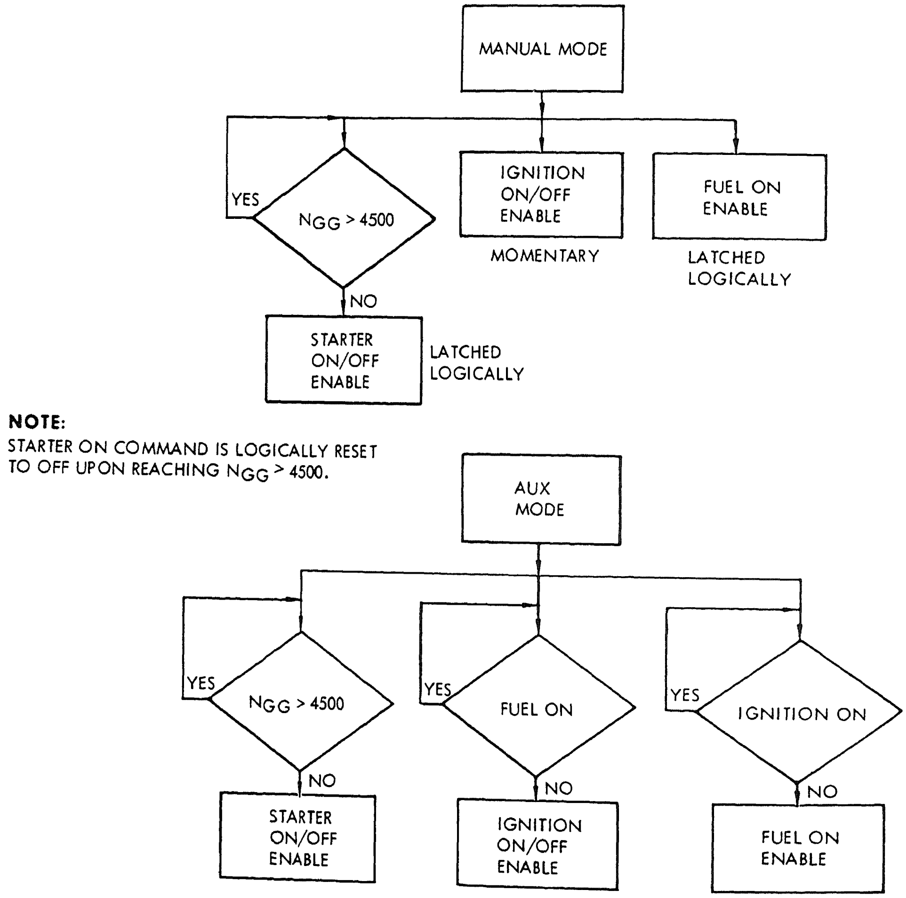

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Figure 7-23.—Manual and auxiliary start logic.

ermocouple Amplifier

The V card is the thermocouple amplifier. It -forms two functions. The first function is to ıvert the $T_{5.4}$ signal into a 0- to 10-volt d.c. ıal proportional to 0 to 2000°F. The second ıction is d.c. to d.c. conversion. This isolates : thermocouples and reference junction from ɔund systems that may cause error inducing ɔund loops.

ınal Conditioner No. 1

The No. 1 signal conditioner (the X card) is requency sensing card. It senses N_{GG} from the gnetic pickup on the accessory drive. The ut signal is conditioned to a voltage level protional to the speed frequency. The level is then npared against adjustable limits to determine en the speed is above 1200, 3500, 4500, 4900,)0, and 9700 rpm.

ınal Conditioner No. 2

The No. 2 signal conditioner (the Y card) proses four signals. Two of these signals are ssure signals from two pressure transducers. ese are the fuel manifold pressure and the GT e oil supply pressure. The third signal comes m the thermocouple amplifier. The fourth ıal is an N_{GG} signal from signal conditioner . 1. The two pressure signals are inputted as ɔ 20 mA directly proportional to the pressure sed by the transducer. These signals are conted to 0- to 10-volt d.c. voltage levels. The $_{4}$ and N_{GG} signals are inputted as 0- to 10-volt . voltages. These four 0- to 10-volt d.c. signals sent to unity gain amplifiers and transmitted ink. The signals are also compared to detect following levels.

- $T_{5.4}$—greater than 400°F
  greater than 1500°F
  greater than 1530°F

- Lube oil supply pressure—less than 6 psig
  less than 15 psig

- Fuel manifold pressure—greater than 50 psig

- N_{GG} signal loss

Signal Conditioner No. 3

The No. 3 signal conditioner (the Z card) is basically a relay driver. It activates the engine run time meter, the engine start counter, the ignition relay, the start air valve, and the ice detector relay. This board also gates the +28 volt d.c. to activate the No. 1 and No. 2 fuel valves.

Logic Card No. 1

The No. 1 logic card (the AB card) develops the control signals from operator commands or control logic. The signals are generated depending on the system status and the type of command to be generated. The first eleven signals generated depend on the reception of the signals received synchronized to the start/stop sequencer timing.

Logic Card No. 2

The No. 2 logic card (the AD card) has three timers used during engine start. These timers measure the following times for the listed functions.

Time	Function
20 seconds	Measured between starter on initiation and the time it takes to reach 1200 rpm. Generates fail to reach 1200 rpm signal.
45 seconds	Measured between starter on initiation and the time it takes to build up 15 psig lube oil pressure. Generates a lube oil supply pressure low after this period. If 6 psig is not attained, a lube oil supply pressure low shutdown command is generated.
90 seconds	Measured between starter on initiation and the time it takes to reach 4500 rpm. Generates a fail to reach 4500 rpm signal.

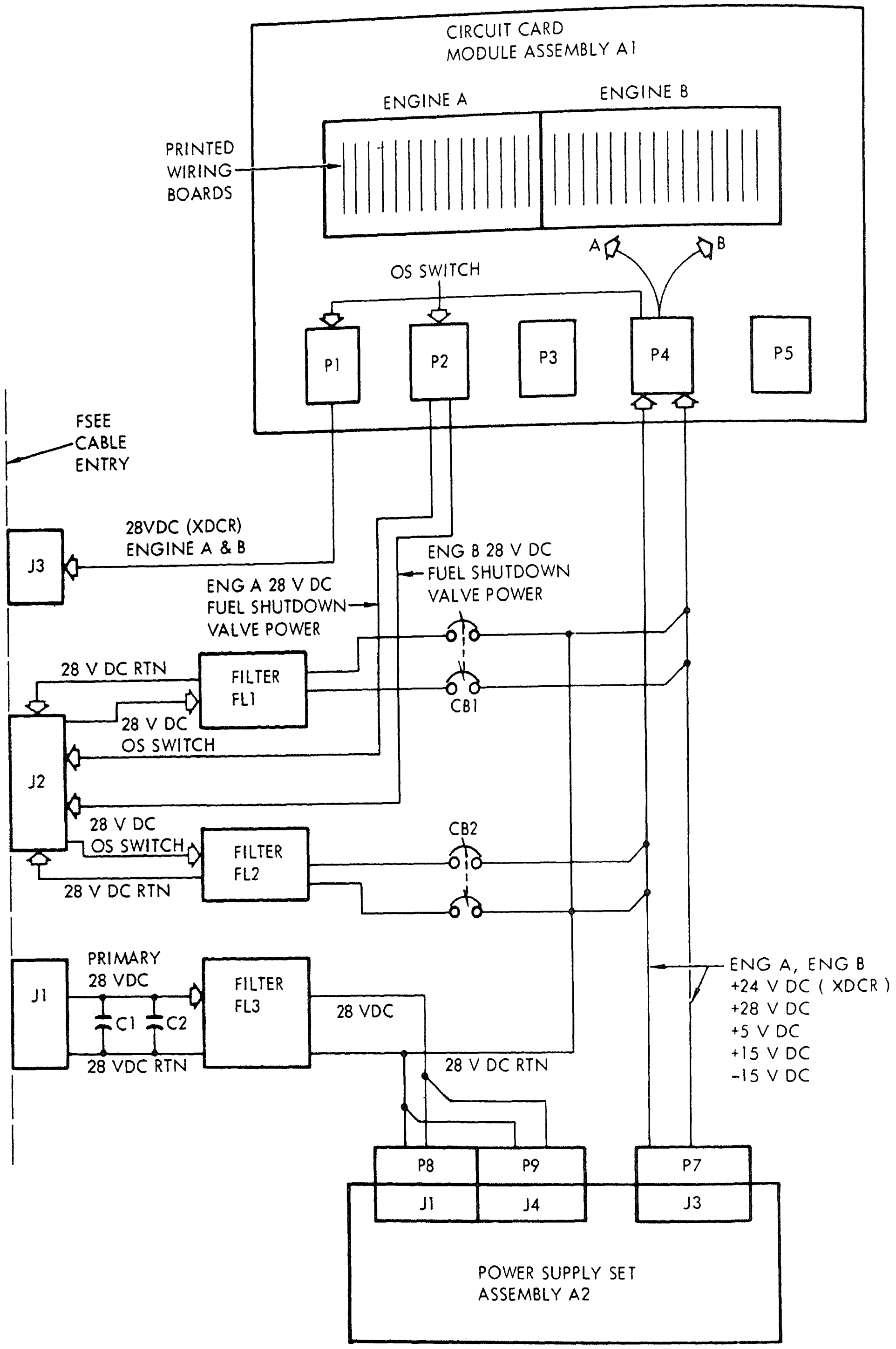

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Figure 7-24.—DD, DDG, CG, FSEE power supply.

gic Card No. 3

The No. 3 logic card (the AE card) performs ven functions, two of which are timing funcons. The first measures 40 seconds from the time e igniters are ordered on. In this time period, 0°F $T_{5.4}$ must be exceeded or a fail to lightoff nal is generated. The second timer measures 300 conds (5 minutes) to allow cooldown between e time a normal stop is initiated and when the op command is issued. Following is a descripn of the other five functions.

- Enables the run time meter and the start counter.
- Detects a flameout and generates a flameout alarm.
- Stores abnormal $T_{5.4}$ status.
- Stores normal ice detector enable and engine run start.
- Monitors status conditions and executes a stop when abnormal conditions exist.

gic Card No. 4

The No. 4 logic card (AC card) provides many nctions. These are timing, power-on reset, PT erspeed reset, alarm reset, status signal generan and processing, fuel valve testing logic, purge ne stop delay counter, and normal stop fail unter.

POWER DISTRIBUTION

The two different models of the FSEE use two fferent power distribution sets. A major fference is that the FFG-7 class FSEE only stributes power whereas the other model FSEE nerates all FSEE voltages from a 28-volt d.c. s. Also, FFG-7 FSEEs use 115 volt a.c. whereas e other models use a lower voltage d.c.

D-963, DDG-993, CG-47 EE POWER

This model receives 28 volt d.c. from the ship's wer supplies to connector J1 (figure 7-24). The exception to this is power to the overspeed switch fuel shutdown valve solenoid. The shutdown valve solenoids are powered by 28 volt d.c. at connector J2. Three filters are used to eliminate high frequency line noise on the three power inputs. (FL1 and 2 are for fuel solenoids. FL3 is for primary power.)

The power supply set A2 has dual redundant power supplies. It distributes power to the circuit card assembly A1. Each pair of redundant supplies feed engines A and B. They are controlled by separate switches in the power supply set. The power supply converts and distributes the following voltages: +5 volt d.c., +15 volt d.c., −15 volt d.c., +28 volt d.c., and +24 volt d.c. for the P_{t2} and $P_{t5.4}$ transducers.

The power supply set has two run time meters to show how long the sets are powered up. They are powered by 24 volt d.c. The set also has the power amplifier for interface between the PLA circuit and the PLA actuator along with the fail to idle relay.

FFG-7 POWER DISTRIBUTION

The FFG-7 FSEE distributes both a.c. and d.c. power for use in the FSEE and in the module. All power is supplied by ship power supplies (figure 7-25). Input power to the FSEE is 115 volt a.c. and +5, +15, −15, +24, and +28 volts d.c.

The 115 volt a.c. is used for the flame detectors, ice detectors, and ignition exciters of both engines. The +24 volt d.c. is used as power for four transducers. These are the P_{t2}, $P_{t5.4}$, lube oil supply, and fuel manifold pressure. The +28 volt d.c. is used as power to the fuel solenoid valves. Each distribution assembly has a circuit breaker for this power. The other voltages are used in the circuit card racks for logic and control. The distribution assemblies also have the PLA power amplifier and the fail to idle relay.

SUMMARY

In this chapter we have discussed the operation and construction of the LM2500 FSEE. We have covered only how it works, not how to repair or adjust it. You must make repair or adjustment

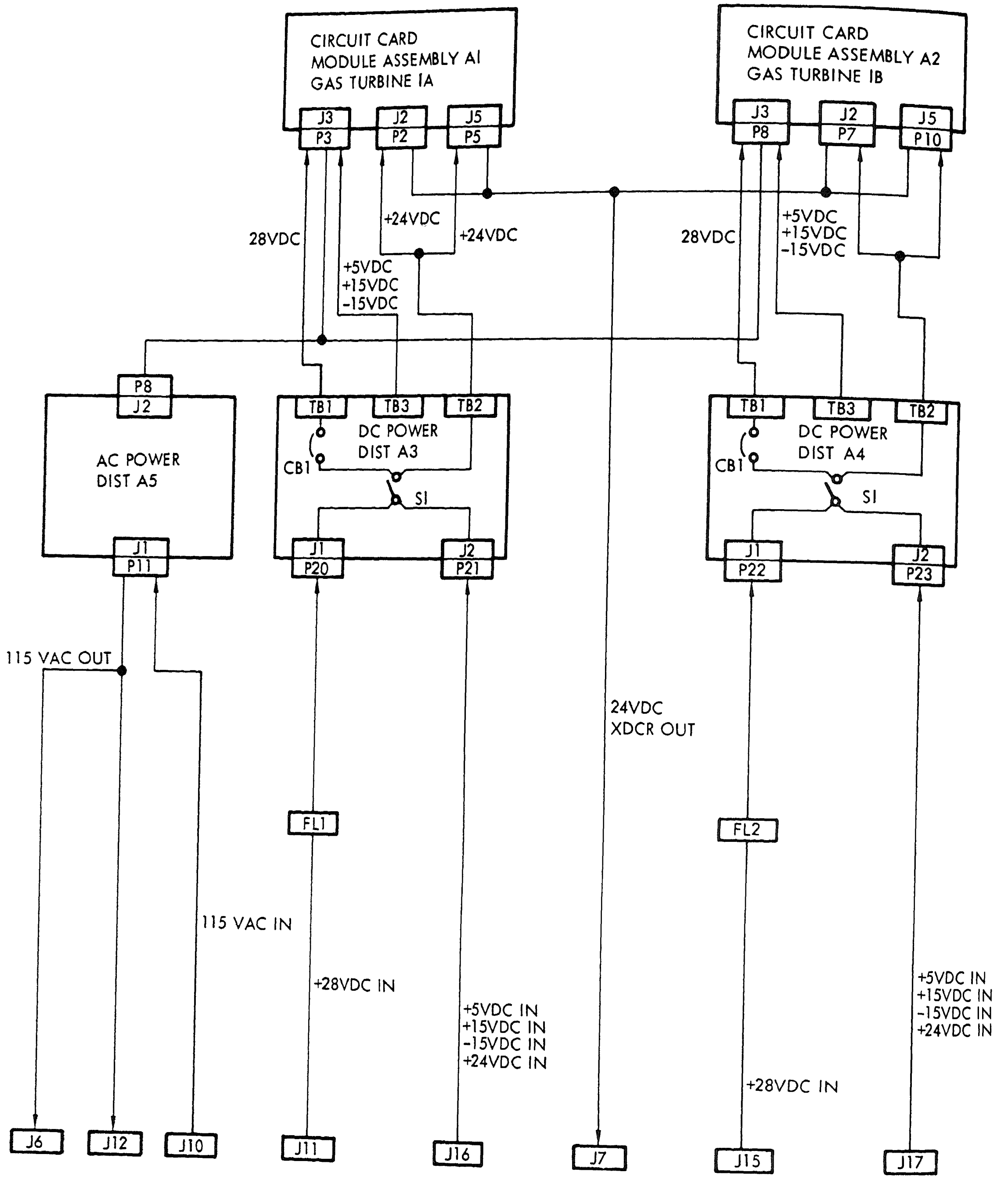

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Figure 7-25.—FFG-7 FSEE power distribution.

operations strictly by following the manufacturer's technical manual. We have presented the information here to allow you to understand what functions are being performed when you make those adjustments. Knowing the information in this chapter should enable you to more quickly identify malfunctions. For more detailed and specialized information on each circuit, refer to the manufacturer's technical manual. Remember, only qualified technicians should make adjustments on the FSEE, and then only when the engine is shut down.

REFERENCE

Propulsion Gas Turbine Module LM2500, Description, Operation, and Installation, Vol. 1, Part 1, S9234-AD-MMO-010/LM2500. Naval Sea Systems Command, Washington D.C., 1 May 1982.

CHAPTER 8

ALLISON 501-K17 GAS TURBINE ENGINE

Until now our discussion has centered on e propulsion uses of GTs. This means we ive covered only part of the job some GSEs e tasked with. On the larger gas turbine ips, such as the DD-963, DDG-993, and G-47 classes, GSEs must maintain the ship's rvice gas turbine generator sets (SSGTGSs GTGSs). These ships use two different TGSs. They are the Model 104 on the DD id DDG classes, and the Model 139 found 1 the CG-47 class. Both types of GTGSs e the Allison 501-K17 engine as a prime over. Although the engine is the same on oth sets, many differences exist between the iits. The Model 104 GTGS is a 2000-kW TGS; the Model 139 is a 2500-kW unit. he 104 has a solid-state LOCOP that uses ialog meters; the Model 139 incorporates digital LOCOP with light emitting diodes EDs) used to display operating parameters. he Model 139 also uses a brushless exciter at replaces the brushes and slip rings found 1 the 104. Many other changes exist between ese GTGSs. Most of these will be discussed detail in this chapter.

Normally the GTGS is not attended while is in operation. It is controlled either at e switchboard or the electric plant conol console (EPCC). Neither of these conol stations can monitor all the parameters the operating GTGS. For this reason a onitor is usually required when making ourly rounds to log these parameters. Most ten these monitors are GSs in the junior aygrades (E-5 and below). Therefore, you eed to be able to quickly identify any npending casualty to the GTGS to prevent loss of the ship's electrical power. To do this, you must first be able to understand how the set is constructed, how its systems function, and how to operate it.

This chapter is written to give you, the junior GSE, enough information to begin qualification as an engine-room equipment monitor. It will also help you with your qualifications as an electric plant control console (EPCC) operator. EPCC operators are the watches that must monitor the electric plant. They are responsible for taking action to prevent loss of the electrical load during a generator casualty.

After reading this chapter and completing the associated NRCC, you should be ready to begin qualifications for the above-mentioned watches. You should also be able to identify and describe engine and generator components. The discussion of the engine systems will allow you to understand the operations of the various engine systems. We will discuss the generator control and monitoring equipment. This information will enable you to understand the procedures for starting, stopping, and motoring a GTG. Some switchboard operations will also be covered. Knowledge in these areas will allow you to understand frequency and voltage control functions.

As with the LM2500, the EOSS is provided to give you the correct procedures for operating this vital piece of machinery. This chapter serves only as a guideline for the operation of a GTG. Always use the EOSS when actually operating any engineering equipment. Using the EOSS will

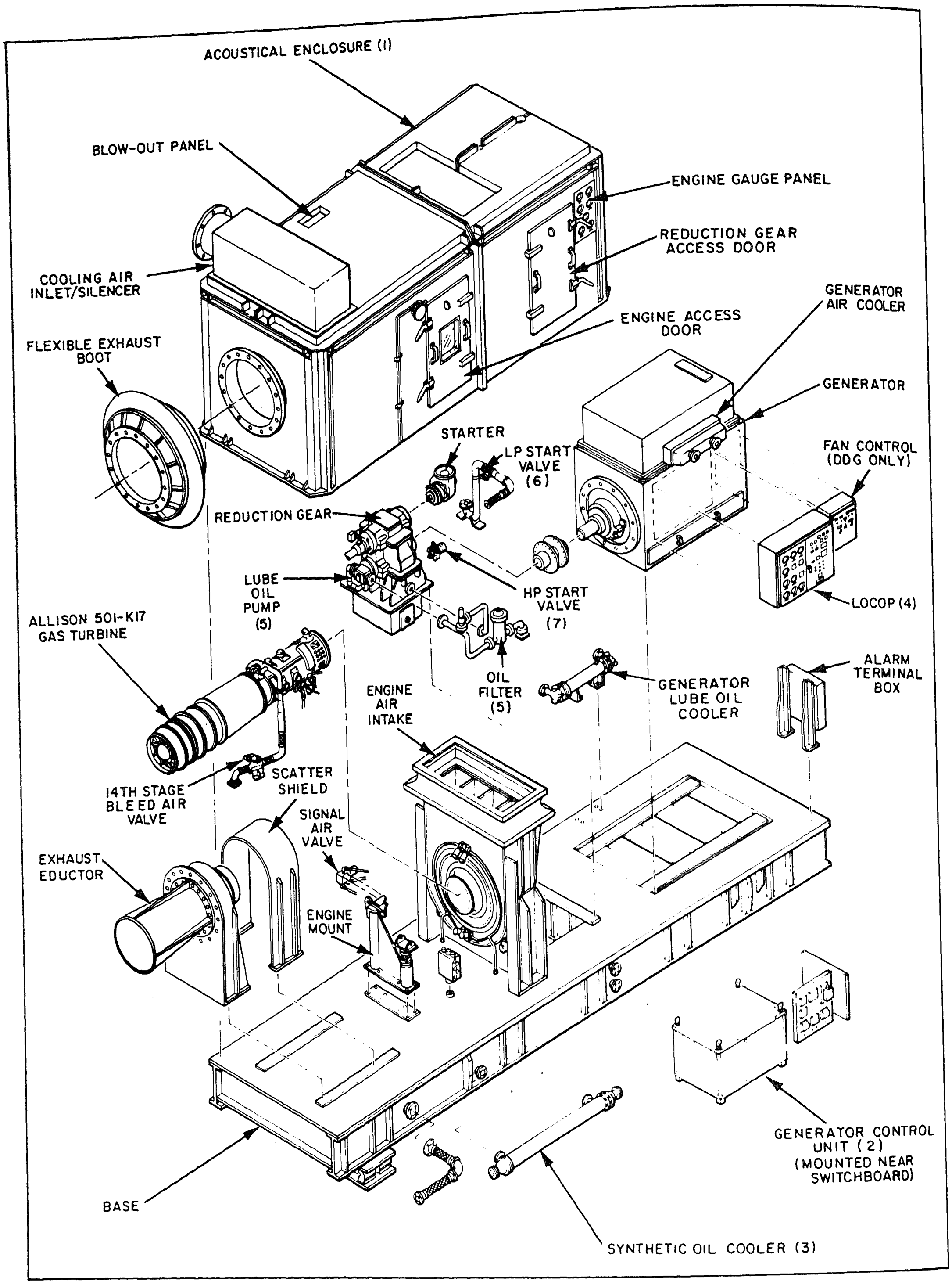

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Figure 8-1.—Model 104 gas turbine generator set.

revent you from missing any steps that could lamage a valuable piece of ship's equipment.

GENERAL DESCRIPTION OF THE GENERATOR SETS

Ship's service electric power is provided by hree 2000-kW GTGSs on the DD and DDG lasses. It is provided by three 2500-kW units on he CG-47 class. Under normal operating condiions, any two generators can supply the entire hip's demand. The third unit can be set up in uto-standby. It will then come on the line utomatically in case either on-line unit fails. Each GTGS is a module consisting of a GT, a reducion gear assembly, and a generator. These are ll mounted on a common base with associated ngine controls and monitoring devices.

Figure 8-1 shows the equipment layout of a generator set. Refer to the numbers listed in parentheses after each description to locate the component in figure 8-1. Each module is about 25 feet long, 7 feet wide, and 9 feet high. The GT and reduction gear assembly are housed in an acoustical enclosure (1). Each generator has a remotely mounted generator control unit (2). The lube oil cooler (3) for each gas turbine/reduction gear system is mounted under the module base. GTGS No. 1 and GTGS No. 2 are located in engine rooms No. 1 and No. 2, respectively, on the second platform opposite the main engines. GTGS No. 3 is located in the No. 3 generator room at the first platform level. This arrangement separates each GTGS by at least three watertight bulkheads. This reduces the chance of loss of electric power because of battle damage.

The GTGSs can be started and monitored at the LOCOP (4) mounted on the generator housing. The LOCOP contains the electronic controls that sequence and monitor the operation of the GTE. The GTGSs can be started remotely at the corresponding switchboard. It can also be controlled at the EPCC in the CCS. Control of generator voltage, frequency, and the generator circuit breaker is available at either the EPCC or the switchboard.

Each GTGS has its own independent seawater cooling system and lube oil system (5). The module is cooled by air supplied from the intake system through an electric fan. Two fans are used on the DDG and CG classes. Support for the module includes other starting air from the bleed air (low-pressure) (6) and high-pressure air systems (7), signal air from the SSAS, emergency cooling water from the seawater service system, fuel from the engine room's FO service system, CO_2 from the fire extinguishing system, and gas turbine cleaning/rinsing solution from the water wash system. Figure 8-2 shows the interrelations of these systems to the GTGS.

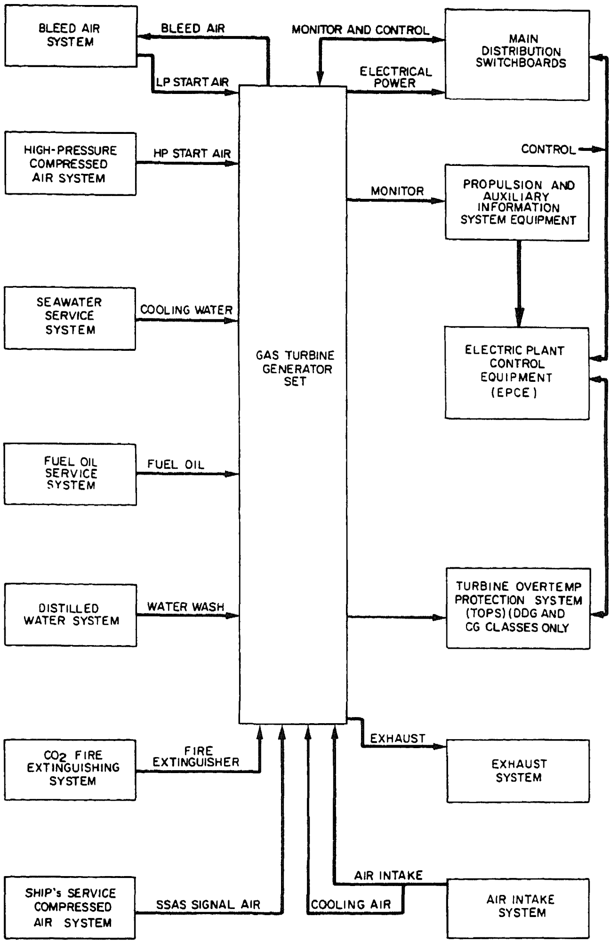

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Figure 8-2.—GTGS interrelation with ship's systems.

Service interface connections are made at the module (figure 8-3).

GTGS MODULE SYSTEMS

The module systems are used to support the operation of the engine. These systems include the base and enclosure, the water wash system, the blow-in and blow-out panels, the cooling air system, the temperature monitoring system, and the fire detection and extinguishing system.

BASE AND ENCLOSURE

The GTGS base is a steel structure attached to the ship's foundation. It is attached by twelve 5,000-pound capacity, shock/vibration isolating mounts. The base supports the entire GTGS system, except two components. One exception is the generator exciter/voltage regulator unit (including the electronic governor). The other is a remotely mounted oil cooler for the gas turbine and the reduction gear lube oil systems. The engine and the reduction gear assembly are housed in an acoustical enclosure (figure 8-4). The enclosure reduces the noise level within the machinery space and provides cooling air for the gas turbine. Barrier walls within the enclosure separate the engine compartment from the reduction gear compartment. They also form the inlet air plenum for the engine.

WATER WASH SYSTEM

Included in the enclosure is an engine water wash system (figure 8-5). The water wash system is used to clean the compressor section of the gas turbine. Two spray nozzles spray chemical cleaner or fresh water into the engine inlet while the engine

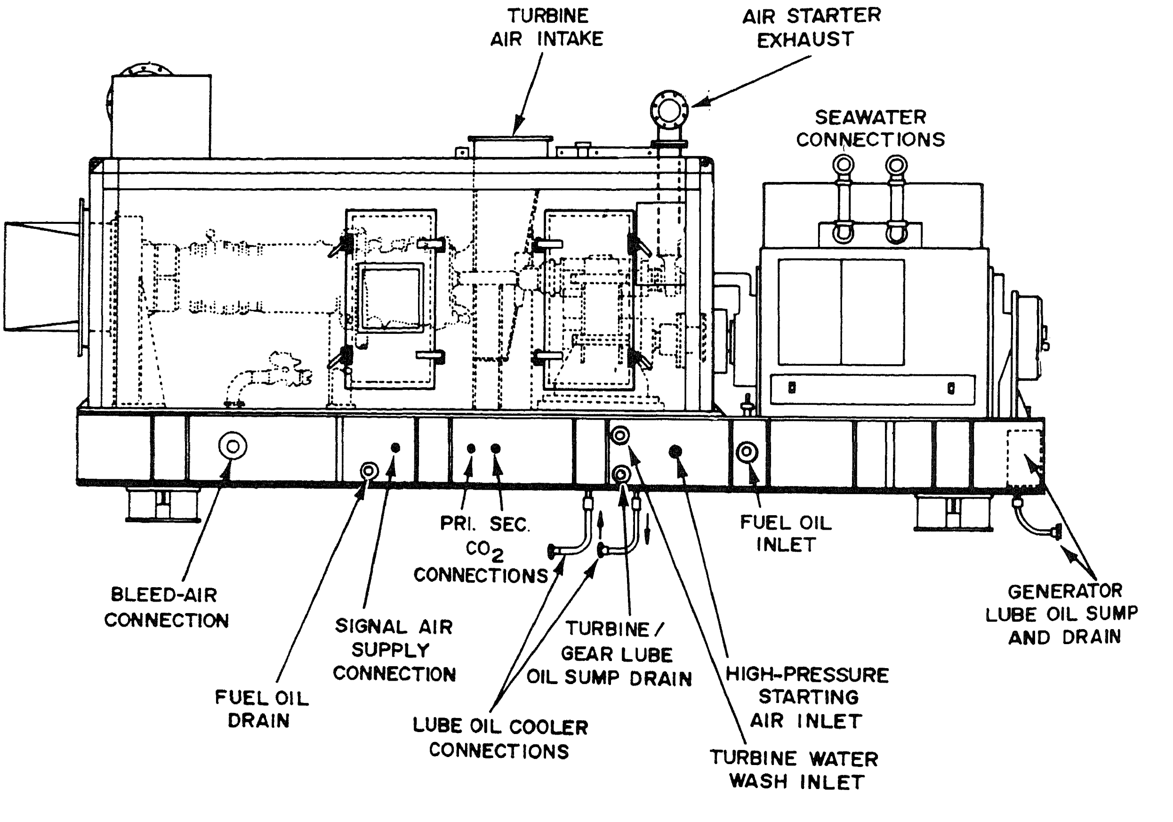

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Figure 8-3.—GTGS ship's system interface connections.

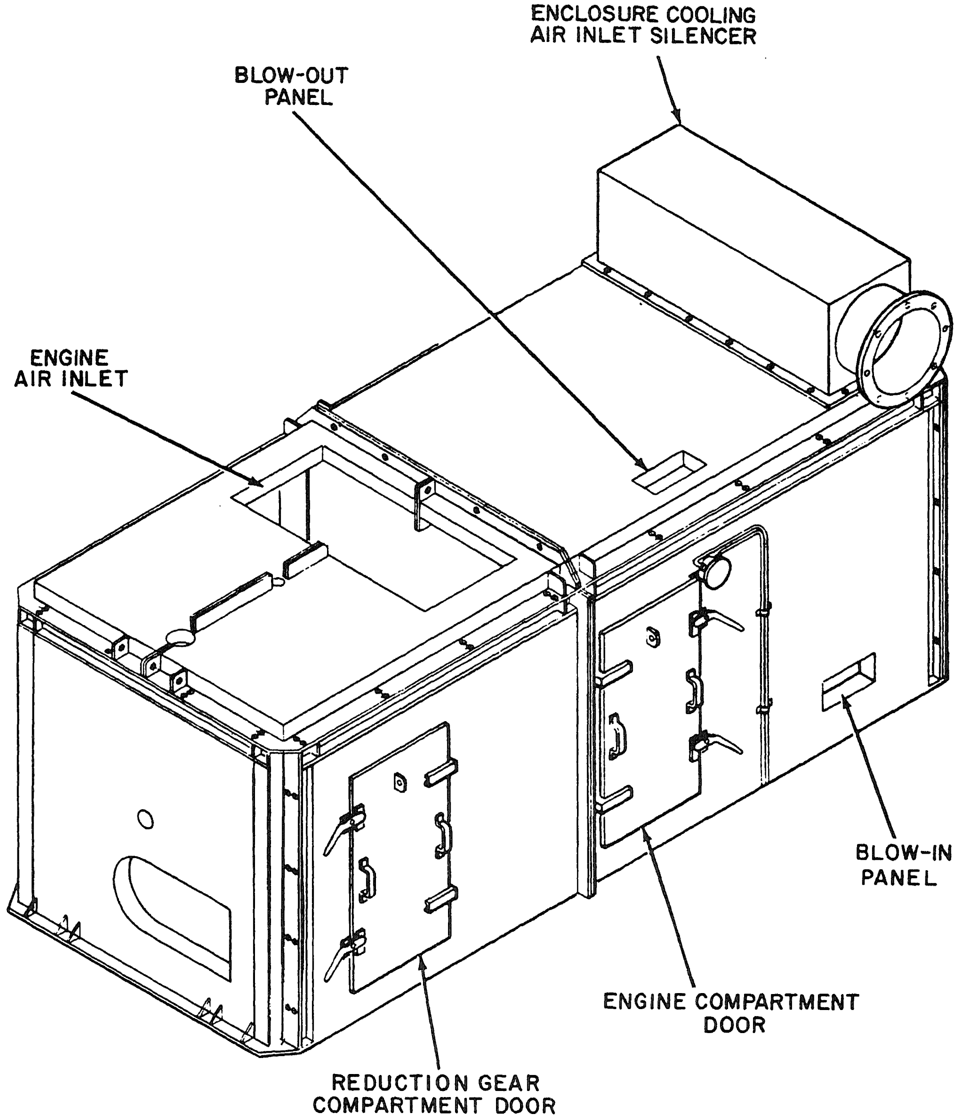

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Figure 8-4.—GTGS enclosure—right side view.

s motoring. The nozzles are mounted in the orward wall of the inlet plenum. Except for the pray nozzles and the solenoid-operated signal air alve, all components of the water wash system re ship's systems.

LOW-IN AND BLOW-OUT PANELS

Blow-in and blow-out panels (figure 8-4) pre-ent damage to the module if high or low pressure occurs within the enclosure. The panels are spring-loaded in the closed position. The blow-in panel is located in the left wall of the enclosure. It is near the aft end and just above the base. The blow-out panel is located in the enclosure roof panel on the left side. It is forward of the cooling air silencer. The locations relate to an observer standing at the exhaust end looking at the intake of the module.

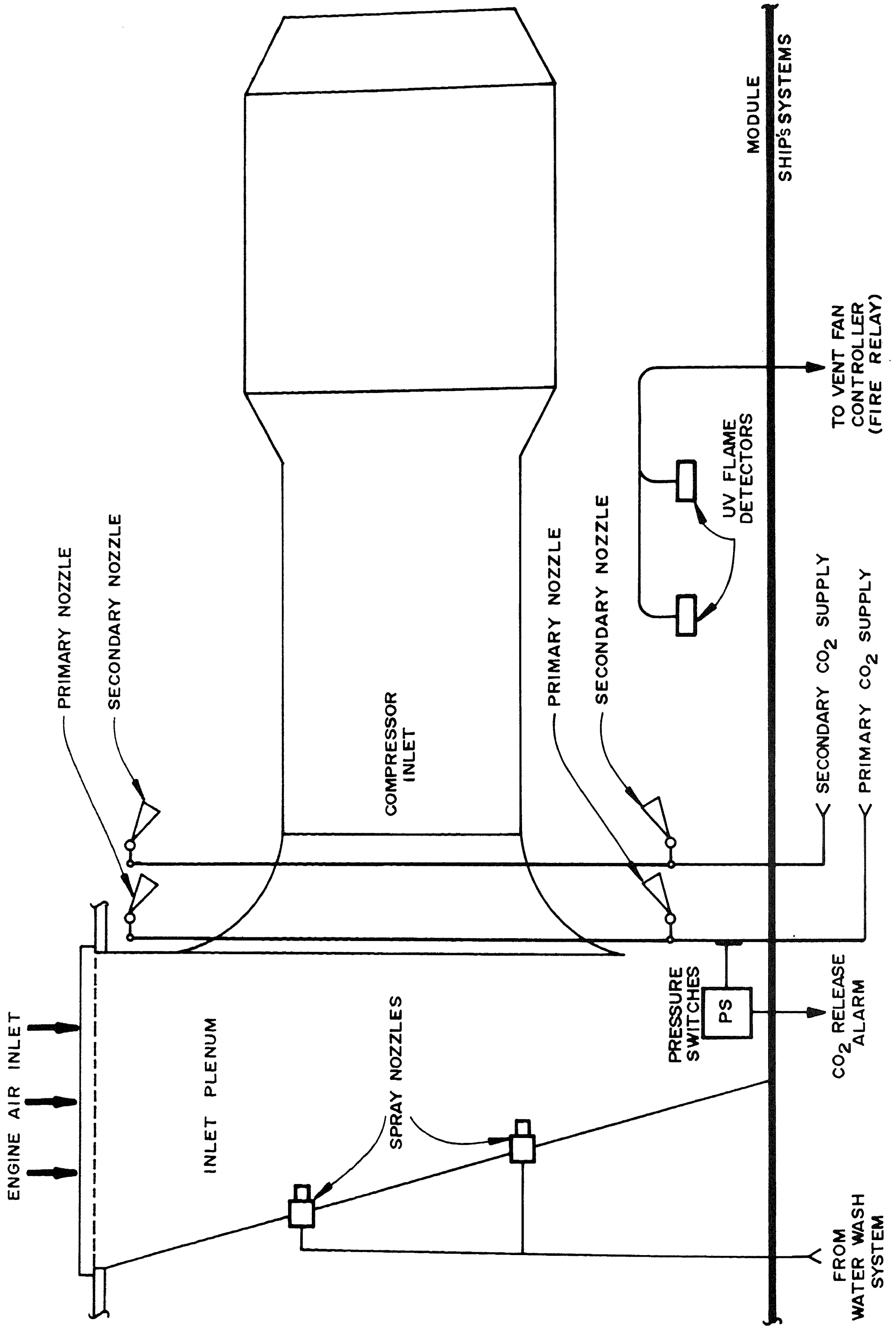

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Figure 8-5.—GTGS water wash and CO_2 systems.

COOLING AIR SYSTEM

Cooling air, extracted from the gas turbine intake duct, flows through a louvered cooling air modulator on the Model 104. Then it flows through an axial fan (two on DDGs and CGs) and a fire damper. Finally it is ducted to the enclosure. The air enters the enclosure through a silencer mounted on the aft (exhaust) end of the enclosure roof. Enclosure ceiling-mounted baffles direct the cooling air to the forward (compressor) end of the enclosure. The air circulates around the engine. It exits through a gap between the engine exhaust nozzle and the exhaust eductor section. Then it mixes with the engine exhaust gas. The fan and the action of the exhaust eductor provide the cooling airflow required during operation.

Module Temperature Monitoring (DD-963 Class)

Two temperature switches, a thermostat, and an RTD are associated with the cooling air system. The components are located inside the acoustical enclosure. One switch controls the cooling air fan, turning the fan on at 195 °F and off at 175 °F. The second switch activates the ENCLOSURE TEMP HIGH alarm indicator at the electric plant control equipment (EPCE). It also activates the summary alarm at the associated switchboard. This occurs when the enclosure temperature reaches 200 °F. The RTD provides a continuous enclosure temperature signal to both the LOCOP and propulsion auxiliary machinery information system equipment (PAMISE). The signal in the PAMISE is used for data logging and the DDIs. The thermostat controls the operation of the louvered cooling air modulator.

Module Temperature Monitoring (CG-47 Class)

Two temperature switches, a thermostat, a manual rotary selector switch, and an RTD are associated with the cooling air system. The manual rotary selector switch is located in the LOCOP. It is a four-position switch: FAN A, FAN B, MANUAL, and OFF. When the selector switch is positioned on FAN A or FAN B, this selects the lead fan. When the LOCOP switch is positioned on MANUAL, you can select a fan by using the LOCOP pushbutton indicators. The fan selected will operate until it is stopped manually. The temperature switches work with the rotary switch to determine which is the lead fan or for manual operation. With the rotary switch in the FAN A position, the A fan will act as lead fan. When the GTG is started, the A fan will start at an enclosure temperature of 170 °F. If the temperature continues to rise, the standby fan B will start at 190 °F. It will continue to run until the temperature drops to 180 °F. When you secure the GTG, the lead fan will continue to run until the temperature drops to a point below 140 °F. In manual mode, each fan will respond to the manual START and STOP pushbuttons except when the fire alarm system is activated.

The RTD in the enclosure activates the ENCLOSURE TEMP HIGH alarm indicator at the EPCE. The RTD on the Model 139 operates like the RTD on the Model 104.

FIRE DETECTION AND EXTINGUISHING SYSTEM

The fire detection and extinguishing system has two UV flame detectors and four CO_2 discharge nozzles (figure 8-5). The flame detectors are mounted on the engine side of the inlet plenum wall. The CO_2 discharge nozzles are mounted in pairs above and below the air inlet housing. Each pair has one primary and one secondary discharge nozzle. The CO_2 is piped to the module from the primary and secondary CO_2 tank banks. When the flame detector detects a fire, an electrical signal from the vent fan controller activates the primary CO_2 system.

GAS TURBINE ENGINE ASSEMBLY

The Allison Model 501-K17 is a single shaft, axial flow gas turbine. It has a 14-stage axial flow compressor, a can-annular combustor, and a 4-stage axial flow turbine directly coupled to the

compressor (figure 8-6). The GT drives the generator through a reduction gear. The reduction gear is mounted in front of the GT. It is coupled to the compressor front shaft by a PTO shaft. The GT and reduction gear are mounted in a common shock-mounted, sound reducing enclosure. The GT is mounted on a suspension system at its approximate center of gravity. It is adjusted so minimum stress is placed on the bolted flanges of the PTO housing. This allows freedom of movement in all planes. This also maintains engine reduction gear alignment when movement occurs because of shock, thermal growth changes, and so forth. The direction of rotation of the engine is counterclockwise when viewed from the exhaust end.

AIR INTAKE

The air intake has a one-piece cast aluminum inlet housing. This forms the airflow path to the compressor. The air inlet housing (figure 8-7) has an outer case, a center hub, and eight struts

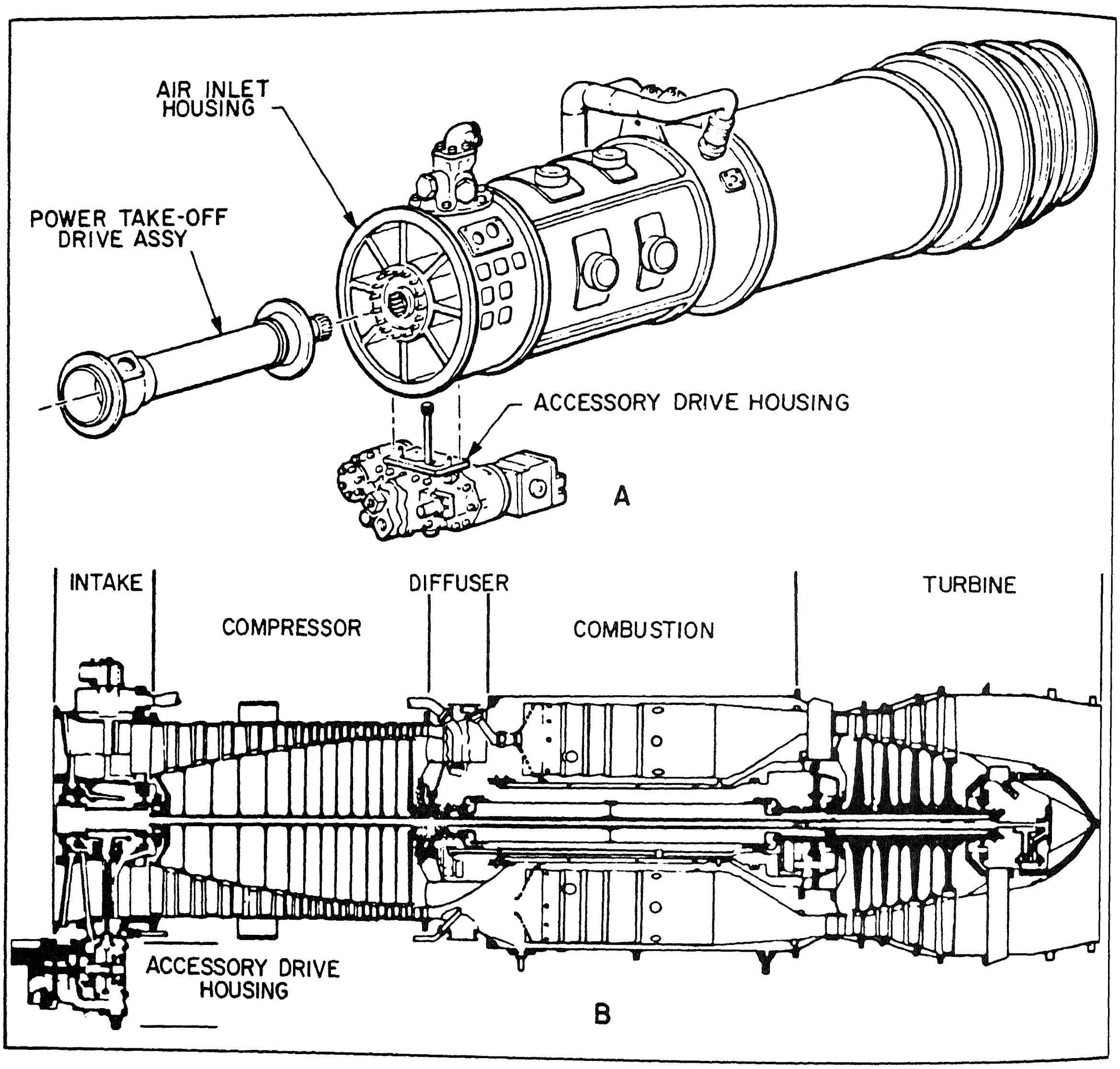

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Figure 8-6.—Allison 501-K17 gas turbine engine; (A) overall view, (B) cutaway view.

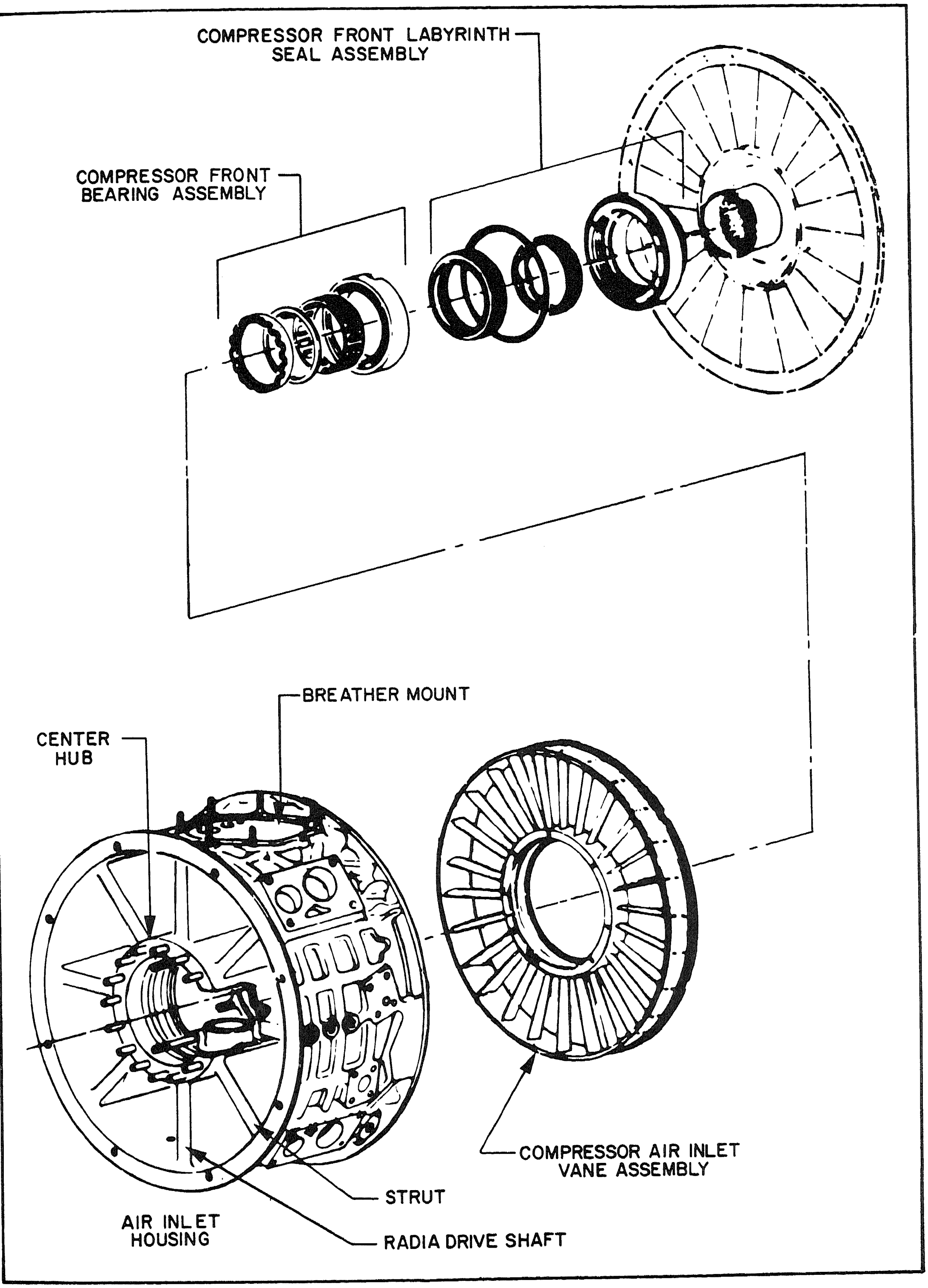

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Figure 8-7.—Air inlet housing, inlet guide vanes, and compressor front frame.

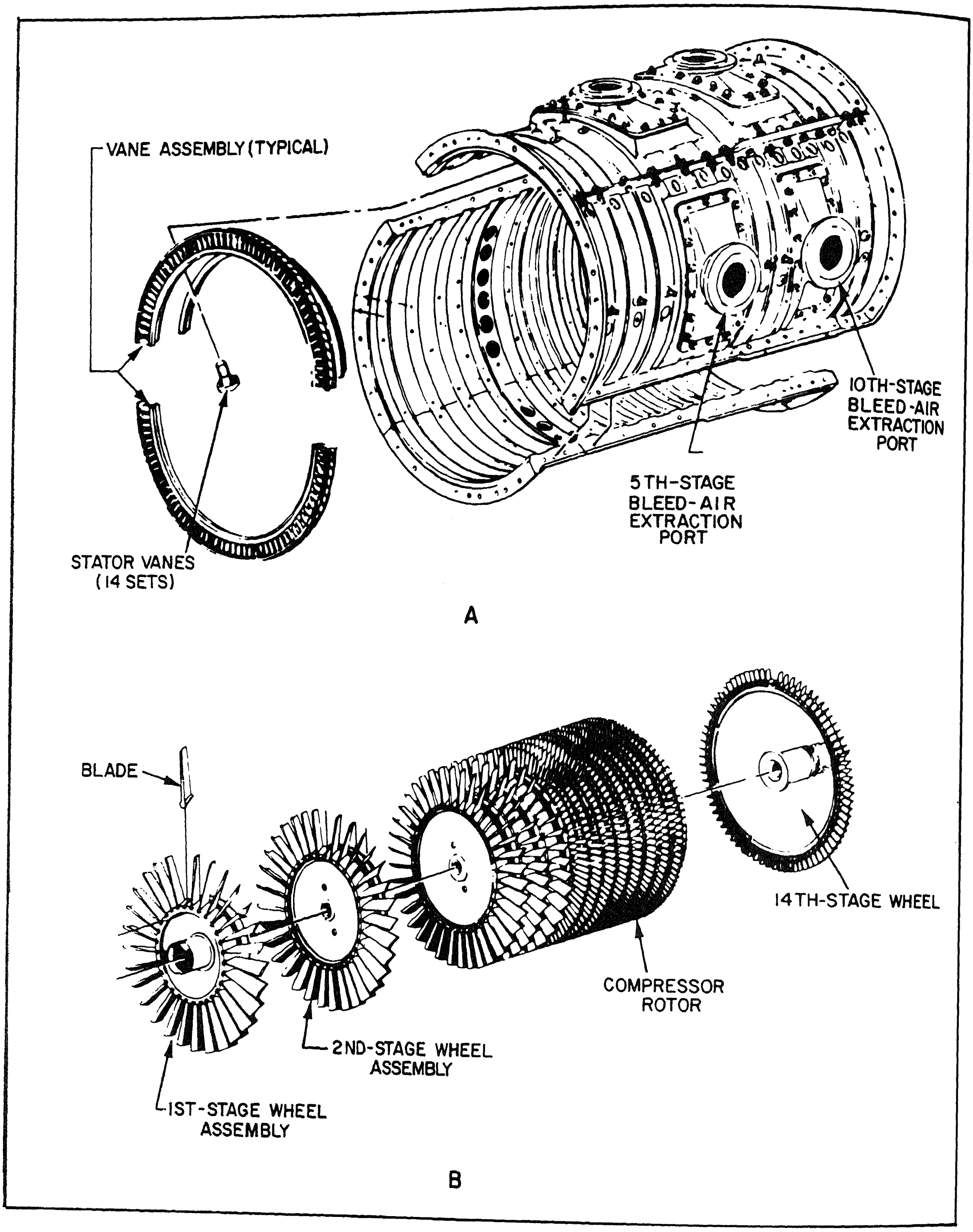

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Figure 8-8.—Allison 501-K17 compressor; (A) stator, (B) rotor.

onnecting the hub to the outer case. The hub ontains the compressor front bearing. This supports the forward end of the compressor rotor, he bearing labyrinth seal, and the bevel gears. These gears are required to drive the accessory earbox. The bottom strut contains the radial drive shaft. The shaft transfers power from the ompressor rotor to the accessory gearbox which s used to drive the accessories. The outer case has pad on the bottom which provides the mounting for the accessory gearbox. The turbine breather is mounted on the top. The housing also has passages for directing anti-icing air to the strut leading edges and the IGV assembly. This assembly is located in the after side of the inlet housing. However, in this application engine anti-icing is no longer used.

COMPRESSOR SECTION

The compressor section has a compressor stator (figure 8-8, item A), a compressor rotor (figure 8-8, item B), and a diffuser (figure 8-9).

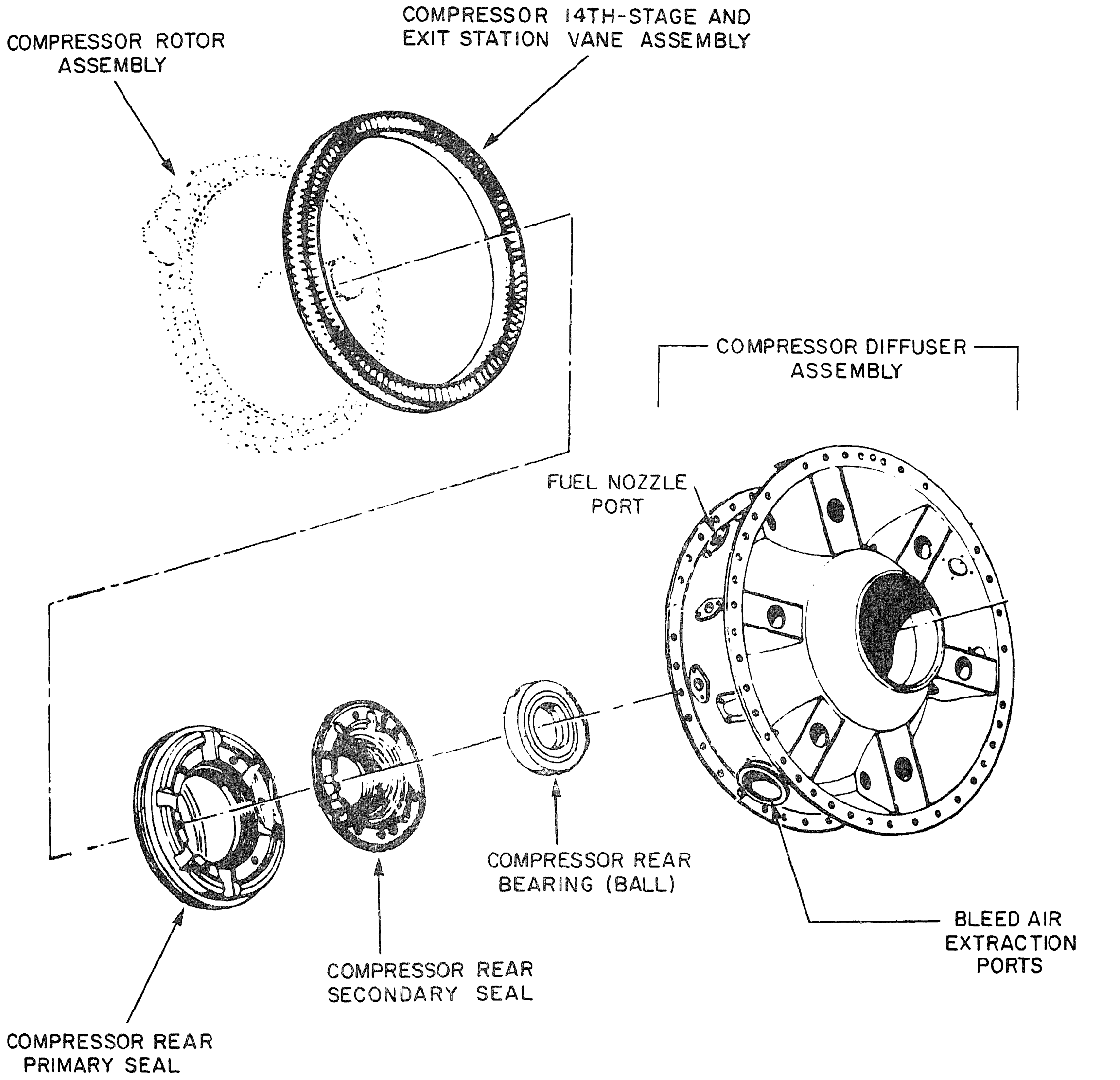

Figure 8-9.—Allison 501-K17 diffuser and 14th-stage stator vane assembly.

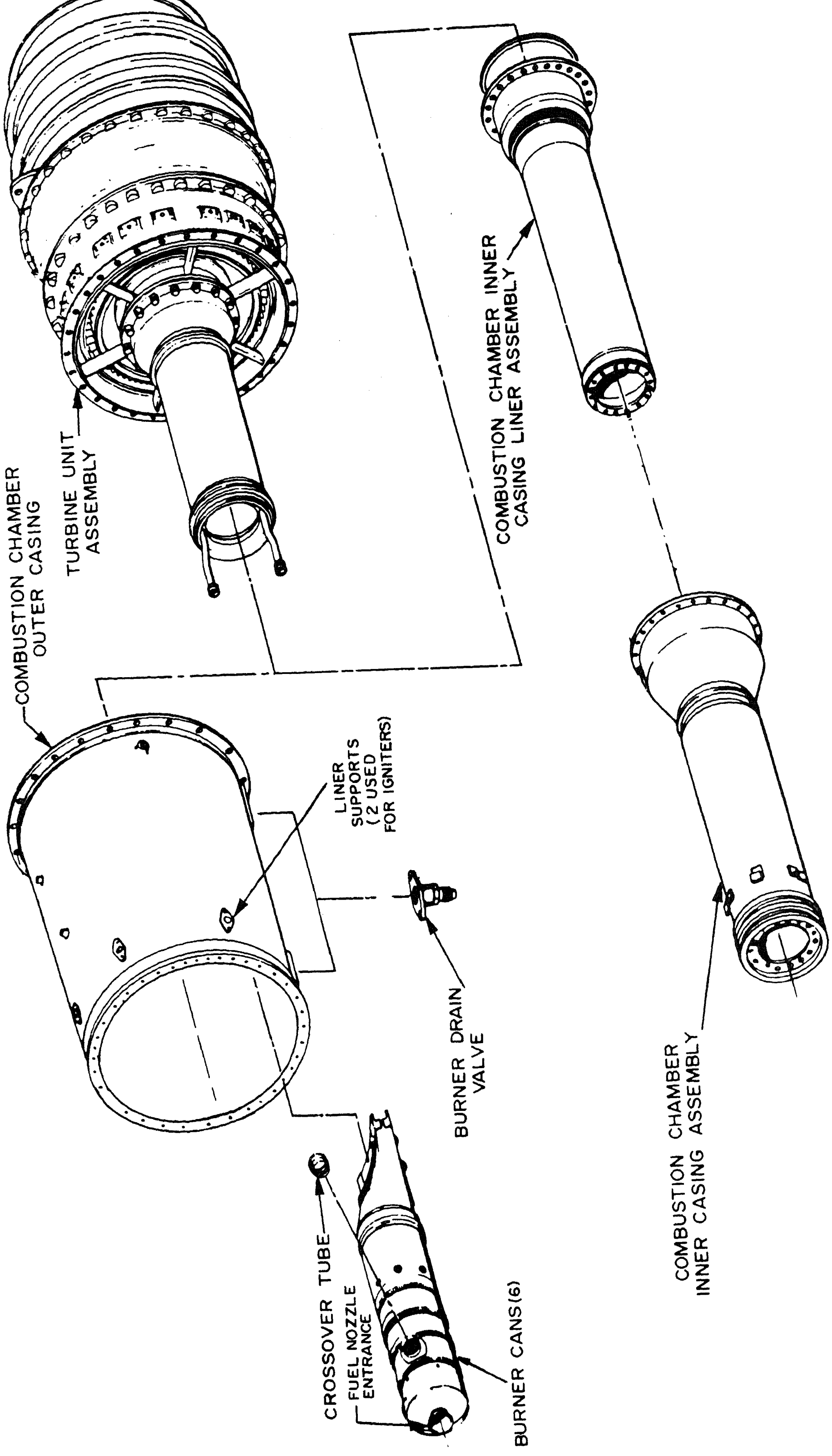

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Figure 8-10.—Allison 501-K17 combustion section.

The air inlet housing described in the preceding paragraph is also part of the compressor section. The compressor case is made up of four sections bolted together along horizontal split lines. The case contains the 14 stages of stator vanes and the exit guide vanes. The rotor is made up of 14 individual wheels. The wheels contain the 14 stages of blades and are pressed and bolted together as one assembly. The diffuser (figure 8-9) is of welded steel construction. It is used to diffuse the compressor discharge air and direct it into the combustor. The diffuser supports the compressor rear bearing/thrust bearing, the compressor seal (two-stage) stationary members, and six fuel nozzles. It also provides three bleed air extraction ports to which a manifold is attached. This allows bleed air extraction (up to 10 percent of total engine airflow) to the ship's bleed air system.

COMBUSTION SECTION

The combustion section has six individual combustion chambers (burner cans) (figure 8-10). They are equally spaced in an annulus formed by a one-piece outer casing and a two-piece inner casing. Six crossover tubes connect the burner cans. These provide flame dispersal during starting. The burner cans are held by the fuel nozzles, turbine inlet vane assemblies, spark igniters (two chambers), and liner supports (six chambers). The burner cans are of welded construction. The outer casing encloses the burner cans and provides the supporting structure between the diffuser and turbine. This casing has two drain valves to drain unburned fuel after shutdown or after a false start. These valves open when combustion pressure drops below 1 to 5 psig. They close above 1 to 5 psig on increasing pressure.

The two-piece inner casing has an inner casing and inner casing liner. These are separated by an air space and bolted together at the front. The inner casing liner has a bellows to take up thermal expansion and contraction. It is bolted to the turbine inlet casing at the rear. The aft end of the inner casing is bolted to the turbine inlet casing. The front end is supported by a sleeve in the diffuser. This provides for thermal expansion and contraction.

About 25 percent of the compressor discharge air entering the combustion section passes to the burner cans. It enters through holes and louvers and mixes with fuel sprayed into the burner cans by the fuel nozzles. The remaining air provides cooling air to the turbine.

POWER/EXHAUST SECTION

The power/exhaust section has several parts: the turbine inlet casing and front bearing support, turbine rotor, turbine front and rear labyrinth seals, turbine vane casing, turbine rear bearing support, and the turbine rear scavenge pump (figure 8-11). The turbine inlet casing and front bearing support house the first-stage vanes, the front turbine roller bearing, and the front labyrinth seal. The front bearing support is bolted to the inlet housing. The second-, third-, and fourth-stage vanes are mounted in the vane casing. The vane casing is a one-piece structure bolted between the aft flange of the inlet casing and the forward flange of the rear bearing support. The turbine rear bearing support contains the rear roller bearing. It also provides the sump for the rear bearing scavenge oil and mounting for the turbine rear scavenge oil pump. The turbine rotor has four wheels containing the turbine blades and is supported at each end by roller bearings. The turbine rotor, coupled to the compressor, extracts energy from the hot exhaust gas. It converts this energy into shaft horsepower to drive the compressor directly. It also drives the generator through the PTO shaft and reduction gear.

ACCESSORY DRIVE

The accessory drive assembly (figure 8-12) (accessory gearbox) provides mounting pads on the front and rear faces. The pads on the rear face are for the fuel pump, governor actuator, and external scavenge oil pump. Pads on the front face are for the speed sensitive valve, main oil pump, and oil filter. The speed sensitive valve is discussed later in this chapter. The accessory drive is driven by the compressor rotor extension shaft. This is accomplished by bevel gears located in the inlet housing which drive a radial shaft. The radial shaft is located in the bottommost strut of the inlet housing. It is connected to the accessory gearbox.

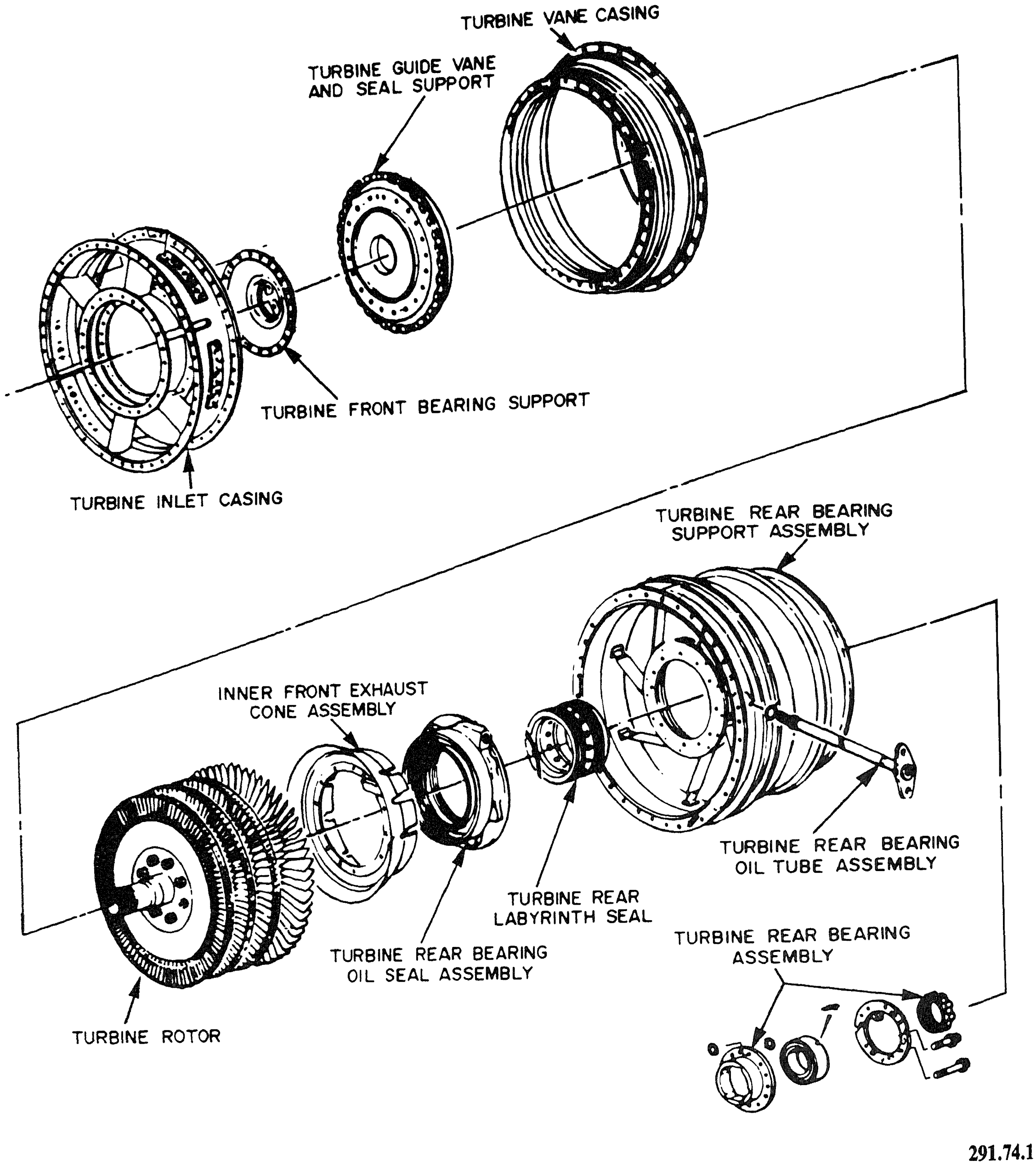

Figure 8-11.—Allison 501-K17 turbine section.

ENGINE FUEL SYSTEM

The fuel system meters and distributes fuel to the engine. This system is used to maintain a constant rotor speed under varying load conditions. Components of the fuel system are both engine mounted and off-engine mounted.

The engine-mounted components on the Model 104 GTGS (figure 8-13) include the following parts: a dual-element fuel pump (1), a low-pressure (LP) fuel filter (2), a high-pressure (HP) fuel filter (3), a pressure relief valve (4), a liquid fuel valve (LFV) (5), an electrohydraulic governor actuator (6), a fuel shutoff valve (7), a manifold

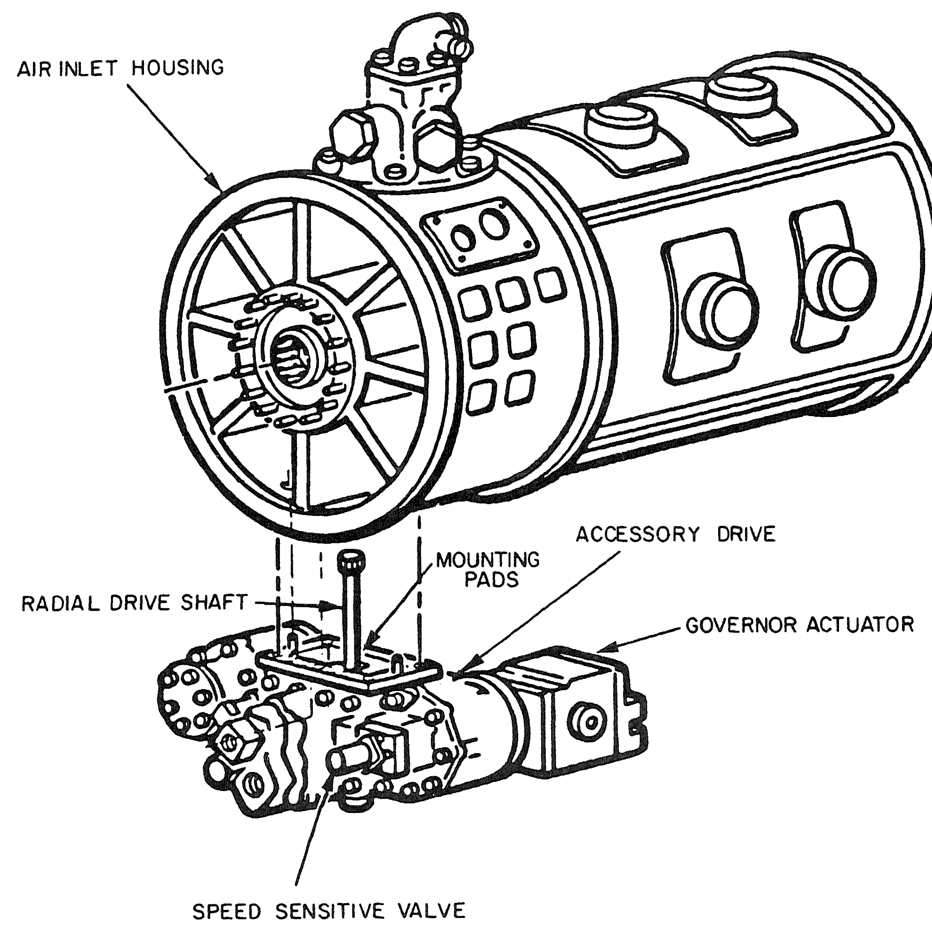

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Figure 8-12.—Allison 501-K17 accessory drive section.

drain valve (8), fuel nozzles (9), and burner drain valves (10).

Off-engine mounted components of the Model 104 are a temperature biased CIT/CDP sensor (11) and a start temperature limit control valve (12). The Model 104 uses the Woodward 2301 governor control system.

The Model 139 fuel system (figure 8-14) is slightly different from the Model 104 fuel system. It does not have the fuel enrichment system found on the 104. Also the Model 139 incorporates an engine-mounted flow divider, two manifold drain valves, dual-entry type of fuel nozzles, and two fuel manifolds. Some of the Model 104 GTGSs are being converted to use these components. Refer to your ship's technical manuals for the system used on your ship. The governor system on the Model 139 is the 9900-320 governor control system. For this adaption the engine is fitted with an electrical CIT sensor, a magnetic speed pickup, and a LFV-mounted linear variable differential transformer (LVDT).

Fuel System Operation Model 104

The following paragraph is a discussion of fuel flow through the fuel system of the Model 104. Refer to figure 8-13 as we describe the operation.

Fuel from a gravity feed tank enters the enclosure and flows into the inlet of the fuel pump. It passes through the pump boost element, through the LP filter, and into the HP elements.

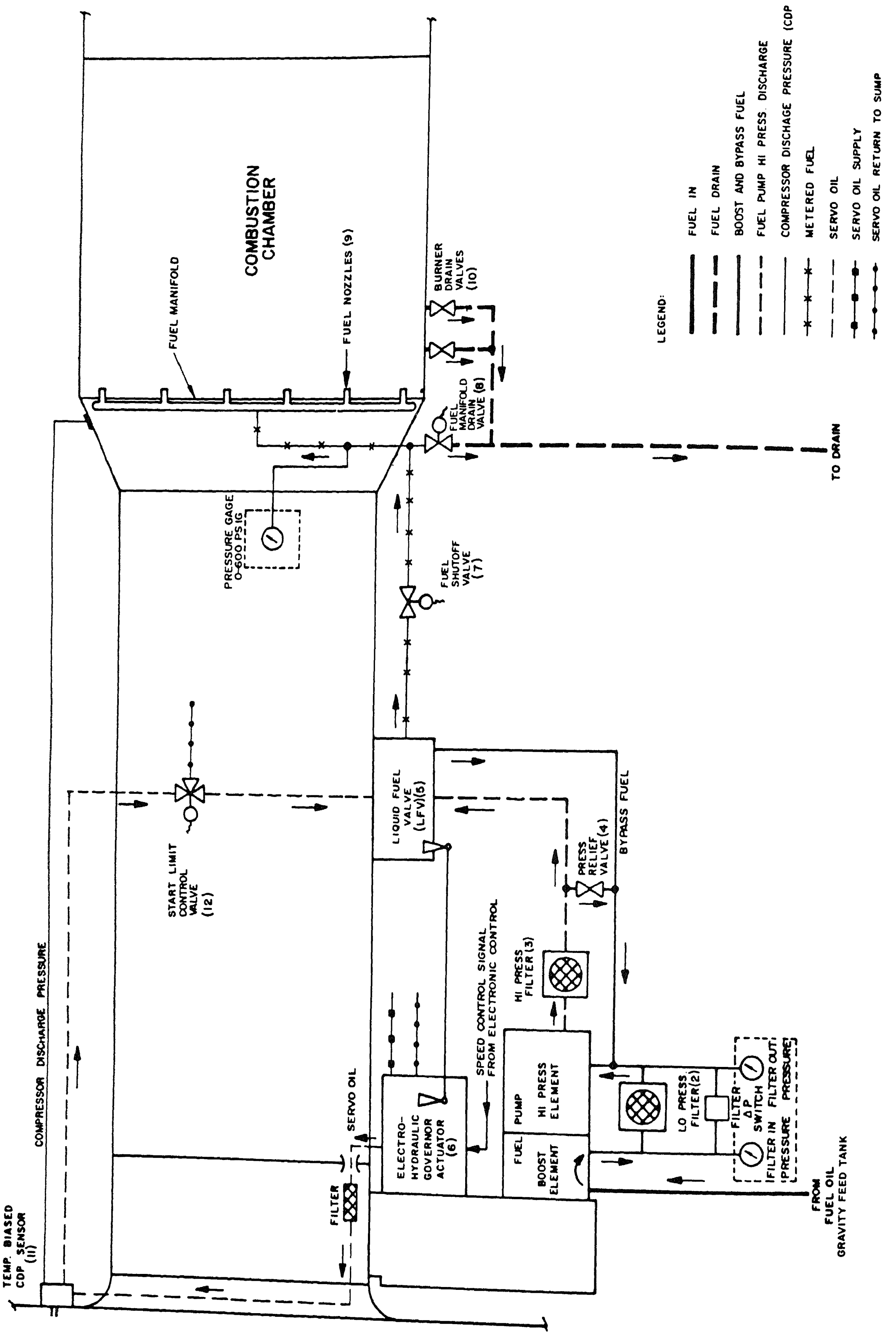

Figure 8-13.—Model 104 fuel system.

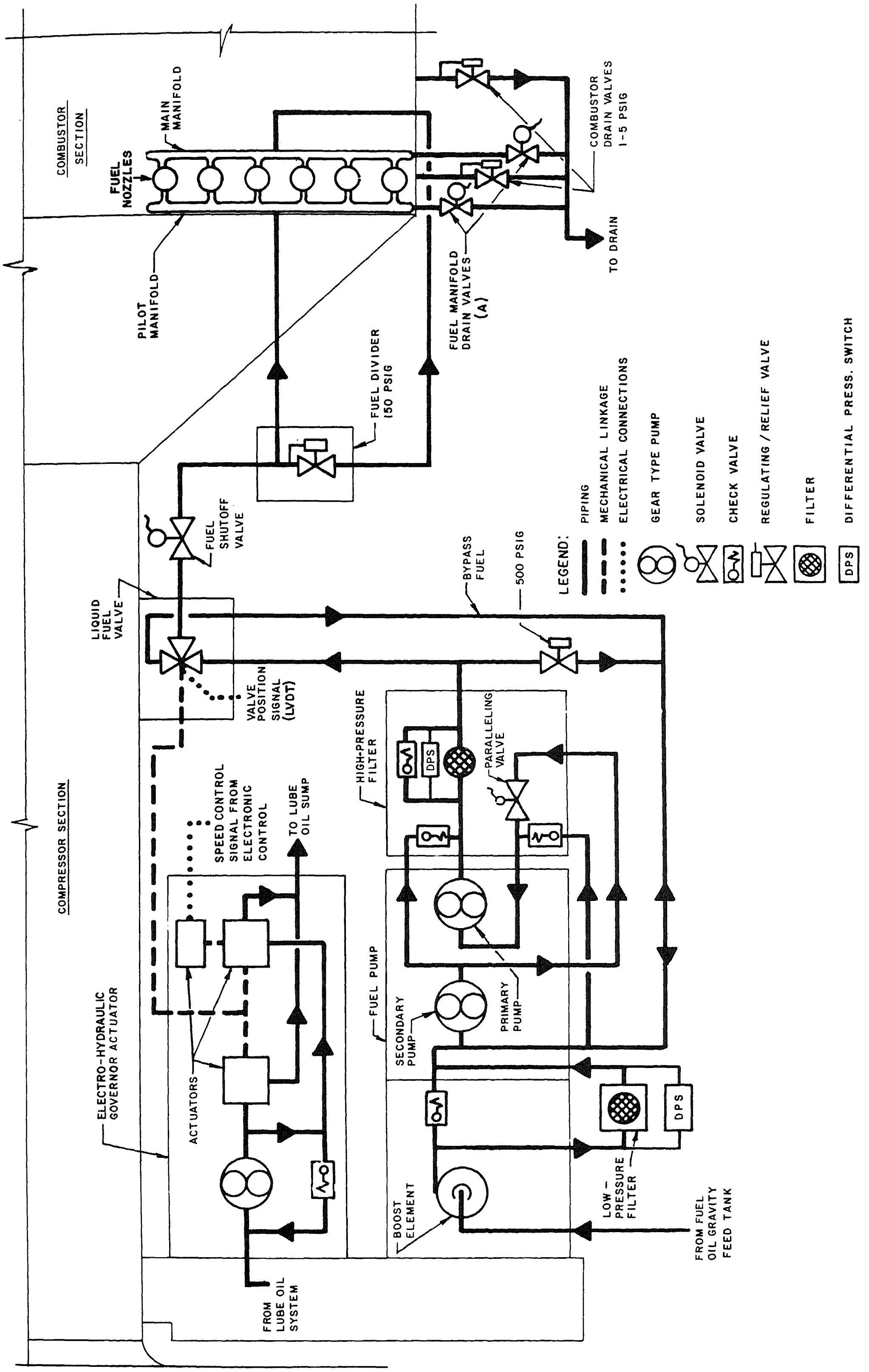

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Figure 8-14.—Model 139 fuel system.

From the pump's HP elements, the fuel passes through the HP filter and into the LFV. Metered fuel from the LFV passes through the fuel shutoff valve. It then flows through the fuel manifold to the fuel nozzles. There it is discharged into the combustion chambers. The fuel pump delivers more fuel than is required. So the LFV bypasses the excess fuel back to the inlet side of the pump's HP elements.

Fuel System Operation Model 139

Fuel system operation of the Model 139 (figure 8-14) is similar to the 104. No fuel enrich feature is available. After the fuel shutoff valve, the fuel goes to the flow divider. Some of the fuel goes directly to the pilot manifold. At 150 psig fuel is also diverted to the main fuel manifold. Two manifold drain valves are also used to drain both manifolds at shutdown. Remember, some Model 104 units have been modified to use this flow divider and dual-entry fuel nozzles.

Fuel Pump

The fuel pump (figure 8-15, item A) is an engine-driven, dual-element pump. It is mounted on the aft right side of the accessory gearbox. The boost element has an impeller-type centrifugal pump and bypass valve. The HP element has a dual-element (primary and secondary) gear-type pump.

In operation, fuel enters the pump, passes through the boost element, then flows externally

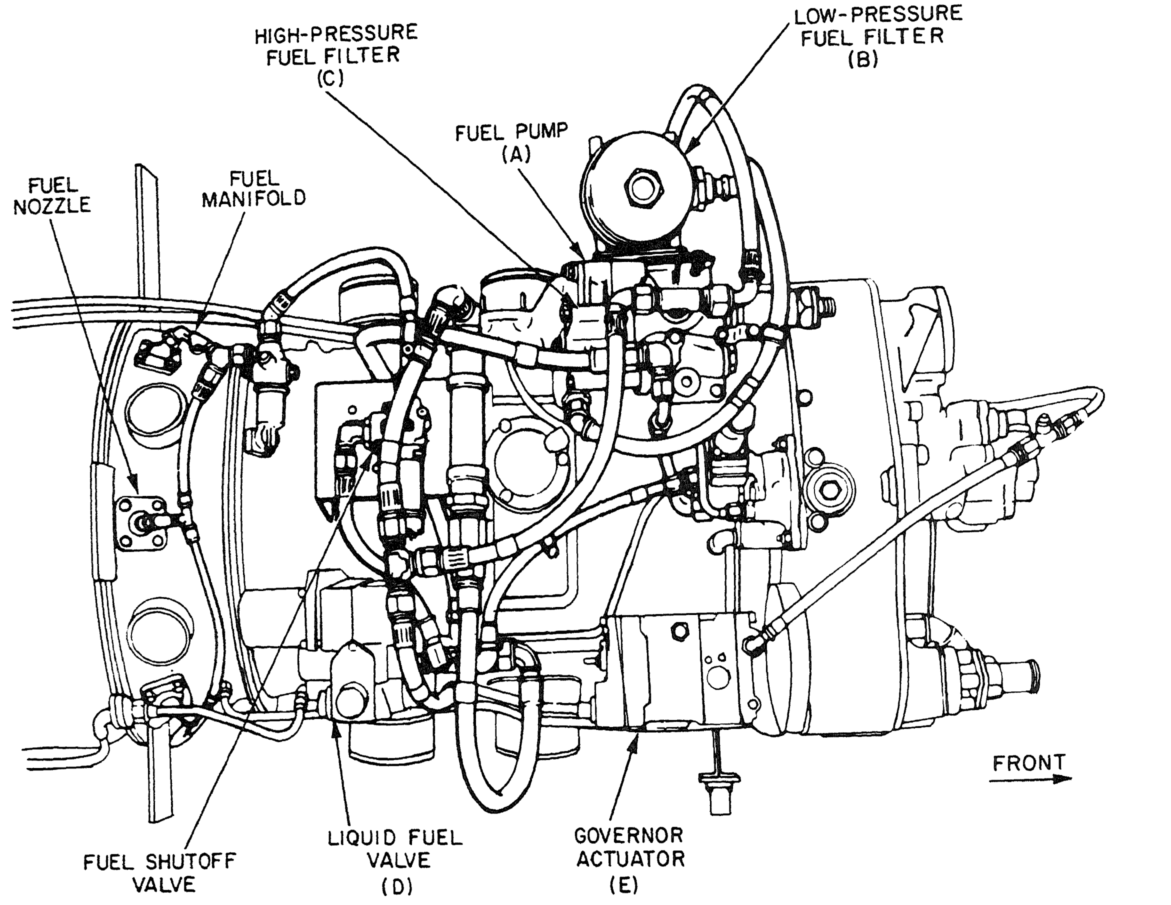

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Figure 8-15.—Fuel system components (bottom view of engine).

rough the LP filter. It then returns to the HP ements through passages in the HP filter sembly. The bypass valve (not shown) opens ly in the event of boost pump failure. Fuel ormally flows in series through the secondary d primary elements of the gear pump. However, e two elements are placed in parallel from about 00 to 8400 rpm by a solenoid-operated parallel-g valve. It is located internal to the fuel pump sembly. From the HP element of the pump, fuel ows to the HP filter.

ow-Pressure Filter

The LP filter (figure 8-15, item B) is a paper rtridge type. It is located in the fuel line tween the boost pump outlet and the HP ement inlet. Relief valves are incorporated in the ter head to bypass the fuel if the filter becomes ogged. Low-pressure filter inlet and outlet essures are shown on the engine gauge panel.

igh-Pressure Filter

The HP filter (figure 8-15, item C) assembly mounted on the bottom of the fuel pump. It s a filter, bypass valve, two check valves, and solenoid-operated paralleling valve. The filter a 33-micron disk type. It is removable for rvicing. The bypass valve opens to permit con-tuous flow if the filter becomes clogged. If one P gear element fails, the check valves permit gine operation from the other element.

essure Relief Valve

The pressure relief valve is closed during rmal engine operation. If the pump discharge essure reaches 500 ± 10 psig above bypass line essure, the relief valve opens. This permits cess fuel to return to the pump.

odel 104 Liquid Fuel Valve

The LFV (figure 8-15, item D) is mounted on e left side of the engine. It is mechanically and draulically connected to the electrohydraulic vernor actuator. The hydraulic connection is rough the CIT/CDP sensor and the start mperature limit control valve. It has a etering valve, an acceleration limiter, and a bypass valve. It meters the required fuel for all engine operating conditions. The electrohydraulic governor actuator linkage and the acceleration limiter (internal part of the fuel valve) control the metering valve position. Thus they control the fuel flow. The acceleration limiter schedules fuel flow during starting as a function of CDP and CIT. During starting and rapid acceleration, the limiter overrides the governor input. This prevents compressor surge (stall) and excessive TIT. The limiter linkage (internal) is actuated by servo oil pressure from the electrohydraulic actuator. This is regulated by the CIT/CDP sensor.

To accurately meter fuel flow, you have to maintain a constant pressure drop across the metering valve. This is done when excess fuel from the pump is returned to the pump by the bypass valve.

Model 139 Liquid Fuel Valve

Like the Model 104, the Model 139 LFV is mounted on the left side of the engine. It is mechanically connected to the electrohydraulic governor actuator. It has a fuel metering valve and a fuel valve position sensor. It meters the required fuel for all engine operating conditions.

The LFV is directly controlled by the governor actuator. During start and running of the engine, the LFV is positioned by the governor to limit the amount of fuel to the fuel nozzles. The governor control circuit receives inputs of engine speed, CIT, fuel valve position, and TIT. The CDP pressure is measured by the LFV. The control circuit sets the LFV through the governor actuator. This provides the proper amount of fuel to the engine for all engine power and acceleration settings.

The fuel valve position sensor is an LVDT. It is mechanically linked to the LFV metering sleeve to sense fuel valve position. The linkage moves the sleeve to the actuator. As it does this, the amount of excitation voltage transmitted to the LVDT output is changed. The output of the LVDT is proportional to the position of the fuel metering sleeve. A comparator compares inputs from the electronic control unit and the LVDT. This is done to correctly position the fuel valve.

Excess fuel from the pump is returned to the secondary pump suction by the bypass valve. Like

the Model 104 LFV, this is done to maintain constant pressure at the metering valve.

Fuel Shutoff Valve

The fuel shutoff valve (figure 8-15) is a normally closed, solenoid-operated valve. It is located in the line between the LFV and the fuel manifold. All fuel to the fuel nozzles must pass through this valve. During the starting cycle, the valve is opened (energized) by the electronic speed switch circuit at about 2200 rpm. The valve is closed by the control circuits to shut down the engine.

Fuel Manifold Drain Valve

The fuel manifold drain valve is a spring-loaded, solenoid-operated valve located at the bottom of the manifold (figures 8-13 and 8-14, items A). It drains the fuel from the manifold to the waste oil drain tank during coastdown. The valve is open (energized) only during the 2-minute period determined by the coastdown timer. Two manifold drains are used on units with the dual-entry fuel nozzles. On the Model 139 these valves are open any time the engine is below 2200 rpm.

Electrohydraulic Governor Actuator

The electrohydraulic governor actuator is engine driven. It is mounted on the left side of the accessory gearbox (figure 8-15, item E). Its output shaft is mechanically linked to the LFV. It receives signals from the electric governor (EG) control box and positions the LFV. The LFV, in turn, meters fuel to the engine. The governor actuator incorporates normal control by the EG system and backup control by a centrifugal governor. Each are alone able to position the output shaft.

An integral oil pump provides servo oil pressure for governor operation as well as other functions. Engine lube oil pressure from the accessory gearbox is supplied to the actuator pump through an external line. During normal operation, an output signal from the EG control box produces a force on an armature magnet. The magnet is attached to a pilot valve plunger and moves the plunger up or down. The pilot valve plunger directs servo oil pressure to change the position of the output shaft. If the electrical signal to the governor actuator is interrupted, it may attempt to overspeed the engine. If this happens, the pilot valve plunger and terminal shaft will be positioned toward the maximum fuel flow position. When the engine speed exceeds the preset limit, the centrifugal governor will assume control of the engine. Flyweights, opposed by speeder spring force, position the pilot valve plunger as a function of engine speed. The pilot valve plunger directs servo oil pressure to position the output shaft connected to the LFV. The centrifugal governor is set to regulate engine speed at about 480 to 580 engine rpm above the normal electric governor operating speed. It has been factory adjusted between 14,300 to 14,400 rpm. This equals between 62- to 62.5-Hz generator output.

Model 104 GTGS CIT/CDP Sensor and Start Temp Limit Control Valve

The CIT/CDP sensor senses both CIT and CDP. It regulates servo oil from the electrohydraulic governor to the acceleration limiter in the LFV in relation to CIT and CDP. The acceleration limiter, in turn, schedules fuel flow as a function of CIT and CDP. During the start cycle above 2200 rpm and during rapid accelerations, the acceleration limiter overrides the input from the electrohydraulic governor. This limits the maximum fuel flow and prevents compressor stall and/or excessive TIT. Below 2200 rpm, the regulated oil pressure from the CIT/CDP sensor is blocked by the start temperature limit control valve. This assures the turbine starts on the minimum fuel flow at lightoff. The CIT/CDP sensor is mounted on the inlet air plenum. The temperature sensing element protrudes into the inlet airstream.

The start limit control valve is a normally open, three-way, solenoid-operated valve. It is located in the regulated servo oil supply line between the CIT/CDP sensor and the LFV (figure 8-13). During the start cycle below 2200 rpm, the valve is energized. This blocks the regulated oil supply and ports the oil from the acceleration limiter (part of the liquid fuel valve) to drain. This causes the fuel valve to remain against the minimum fuel flow stop until the engine reaches 2200 rpm. Between 2200 and 12,780 rpm, the valve is normally de-energized (open). However,

TIT exceeds 1500 °F, the valve is intermittently nergized/de-energized until temperature drops elow 1500 °F. Above 12,780 rpm, the valve is lectrically locked out of the system (de-nergized).

lodel 139 CIT Sensor

The CIT sensor monitors the ambient air mperature. It applies an input reference signal) the speed correction and acceleration mperature reference circuits in the electronic fuel ontrol system. Speed correction is the voltage om the speed frequency sensor corrected by the IT. This results in increased fuel as CIT ecreases. CIT bias is used during all evolutions f engine operation. The CIT sensor is mounted n the inlet air plenum. The temperature sensing ement protrudes into the inlet airstream.

lodel 104 Fuel Manifold and Nozzles

The fuel manifold has sections of steel-braided ose that connect the six fuel nozzles together. he sections of hose also connect the nozzles to drain valve at the bottom of the engine. Fuel utput from the fuel shutoff valve is also con-ected to the manifold. The fuel nozzles are air last type. They have the following parts: a body older, filter screen, filter screen spring, check alve assembly, a pressurized spray tip, and an r blast shroud. When fuel manifold pressure is bout 150 psig or less, the fuel flow is through e pressurized spray tip. This creates a spray attern for starting and for stable combustion at w engine speeds. When fuel manifold pressure xceeds about 150 psig, the check valve opens. uel then flows through the main orifices, iagonally outward from the air blast shroud virlers. The fuel mixes with compressor discharge r flowing from the swirlers to form a finely omized fuel spray pattern.

lodel 139 Flow Divider, Fuel lanifold, and Fuel Nozzles

Fuel flow from the fuel shutoff valve is irected to the manifolds by the flow divider. The divider has an internal pressure-actuated valve. The flow divider, during start-up, allows fuel to be supplied to only the pilot manifold. When fuel pressure reaches about 150 psig, the valve opens. This allows fuel to be supplied to the main manifold.

Two fuel manifolds, pilot and main, supply fuel to the six fuel nozzles. Both manifolds are Teflon-lined hoses with braided steel armor. Each manifold is fitted with a solenoid-operated drain valve at its bottom. The pilot manifold receives fuel from the flow divider during start-up and normal operation. It distributes the fuel to the pilot connection on each of the nozzles. The main manifold receives fuel from the divider only after the pilots have been ignited. After fuel pressure from the control valve is at about 150 psig, fuel is supplied to the main connection of each fuel nozzle. The six nozzles are positioned to extend into their respective combustion liners. This is the optimum location for fuel/air mixing and combustion. Fuel from the pilot manifold flows through the center hole in the top of each nozzle. This forms a spray pattern in the combustion liner. Main manifold fuel is supplied to the holes in the periphery of the nozzle tip. From there it is sprayed into the combustion liner and mixed with compressor air for combustion.

Some Model 104 GTGSs are fitted with modification kits. They allow use of the external flow divider and dual-entry fuel nozzles. Consult your ship's technical manuals for the design used on your ship.

ENGINE LUBE OIL SYSTEM

The lubrication systems on the Model 104 and Model 139 are almost identical. The engine receives lube oil from the GTGS reduction gear lube oil system.

The engine and reduction gear lube systems share a common supply tank, filter, and cooler. The supply tank is the reduction gear sump, while the filter is base mounted inside the reduction gear section of the enclosure. The oil cooler is mounted

remotely under the module (figure 8-16). Synthetic oil, MIL-L-23699, is used in this system.

The engine lube system is a low-pressure, dry sump system. It incorporates the following components: a combination lube and scavenge pump (1), an external scavenge pump (2), a turbine scavenge pump (3), a pressure regulating valve (4), an oil filter and check valve (5), a filter bypass valve (6), and a scavenge pressure relief valve (7).

In operation, oil from the reduction gear sump (supply tank) is picked up by the reduction gear supply pump. It then flows through the supply filter and through the oil cooler. Oil from the cooler supplies both the reduction gear and engine lube oil systems. Oil to the engine flows through a regulating valve and into the inlet of the engine lube pump. From the engine lube pump, the oil flows through a filter and check valve. It then flows through drilled and cored passages and internal and external lines to areas of the engine needing lubrication.

Scavenge oil is collected by the scavenge element of the main lube and scavenge pump, the external scavenge pump, and the turbine scavenge pump. Oil from the turbine scavenge pump flows through drilled passages and internal lines to the accessory gearbox. There it is picked up by the scavenge element of the main pump. Flow from the external scavenge pump joins the flow from the main scavenge pump. This is through external lines and is returned to the reduction gear sump. The magnetic drain plugs (not shown) are on the bottom of the accessory gearbox and the discharge of the main scavenge pump. These collect any steel particles in the oil.

Main Pressure and Scavenge Oil Pump

The main pressure and scavenge oil pump assembly is mounted on the front of the accessory gearbox. It has two gear-type pumps, one each for the supply and scavenge systems. It also has a pressure regulating valve. Oil is pumped by the pressure (supply) element of the pump to the following components: the compressor extension shaft bearing, the PTO shaft midbearing, the accessory gearbox, the engine four main bearings, and the electrohydraulic governor actuator. The main shaft splines are lubricated by the oil returned by the rear turbine scavenge pump. The scavenge element picks up scavenge oil in the accessory gearbox. The oil has gravity drained from the compressor extension shaft bearing and the compressor front bearing. The scavenge element returns the scavenge oil, along with the oil from other scavenge pumps, to the reduction gear sump. An indicating type of magnetic plug is located in the scavenge side of the pump.

Oil Filter

An oil filter is mounted on the front of the accessory gearbox. It has a pleated-type element and incorporates a Teflon-seated, poppet-type check valve. This valve prevents oil from draining into the engine when the engine is shut down. A bypass valve, located in the accessory gearbox front cover, opens at a specific pressure differential. This bypasses the filter if it becomes clogged.

External Scavenge Pump

The external scavenge pump is a three-gear, dual-element pump. It is mounted on the aft side of the accessory gearbox. It scavenges the oil from the compressor rear bearing sump and from the turbine forward bearing sump. The oil from the pump is combined with the scavenge oil from the main scavenge pump. It is then returned to the reduction gear sump.

Turbine Scavenge Pump

The turbine scavenge pump is a gear-type pump. It is mounted in the rear turbine bearing support assembly. A splined coupling drives the turbine-to-compressor tie bolt. The pump scavenges oil from the turbine rear bearing and returns it to the accessory drive housing. It is covered by a thermal insulation blanket and the exhaust inner cone.

Vent System

The air inlet housing cavity and accessory gearbox are vented. This is through an external line to a breather mounted on top of the air inlet housing. Seal leakage air from the compressor rear bearing seal is vented through the two

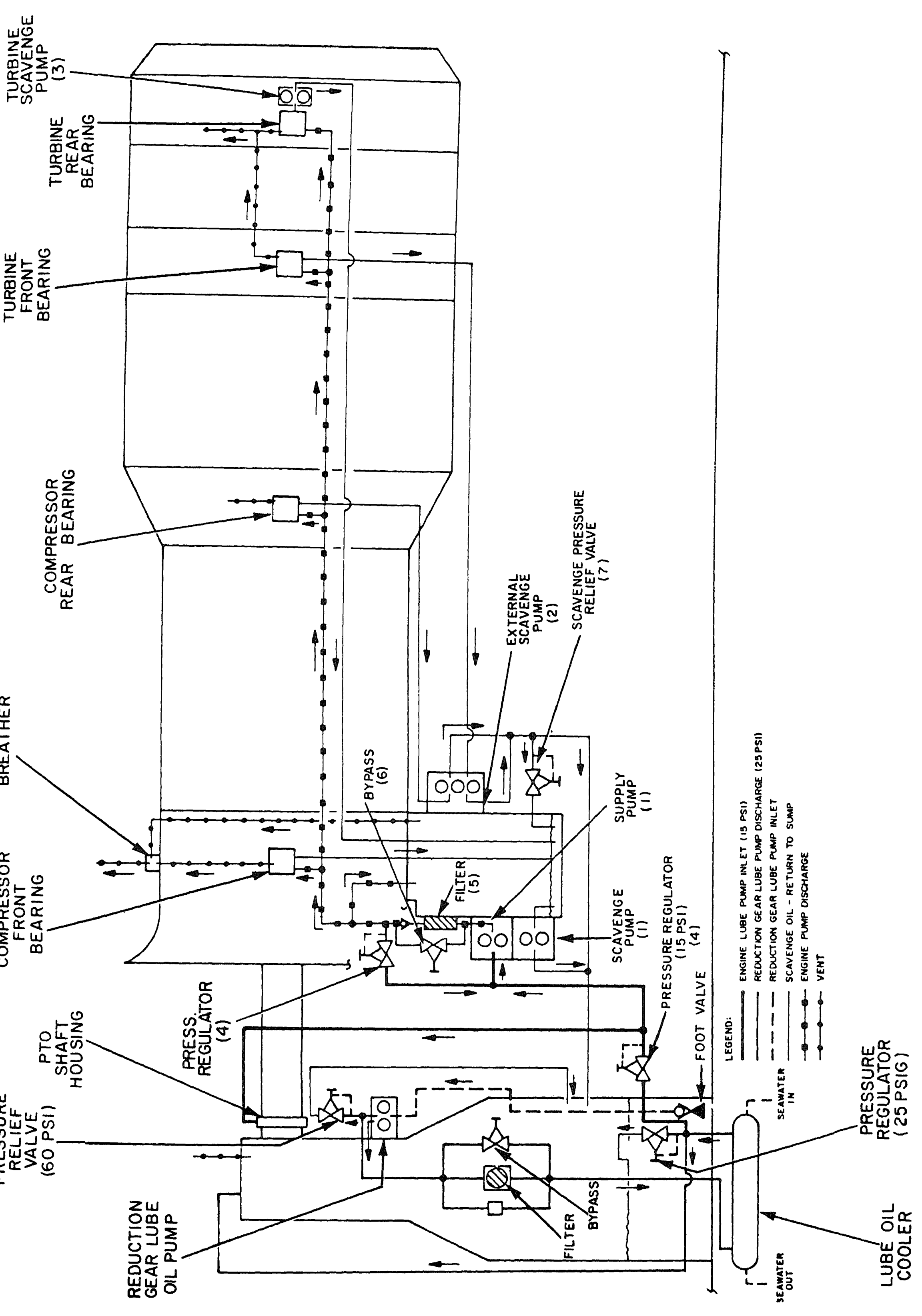

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Figure 8-16.—GTGS synthetic lube oil system.

horizontal struts of the compressor diffuser. The combustor inner casing is vented to atmosphere through two horizontal struts in the turbine inlet casing. The combustion inner casing liner is used to provide a passage for down the shaft venting. This flows through holes in the turbine coupling shaft. From there it flows to and pressurizes the turbine rear bearing labyrinth seal up to the rear face of the turbine fourth-stage wheel to enter into the exhaust gas stream.

IGNITION SYSTEM

The ignition systems of the two types of GTGSs are identical. The ignition system (figure 8-17) has an ignition exciter, high-tension leads, and two spark igniters. The system operates on +28 volts d.c. However, proper operation can be obtained over a range of +14 to +28 volts d.c. Power is supplied to the system through an electronic speed switch actuated relay. This energizes the system at 2200 rpm and de-energizes at 8400 rpm during the starting cycle.

Ignition Exciter

The ignition exciter is a sealed unit mounted on the right side of the compressor. It is a high-voltage, capacitor-discharge type of exciter. It is

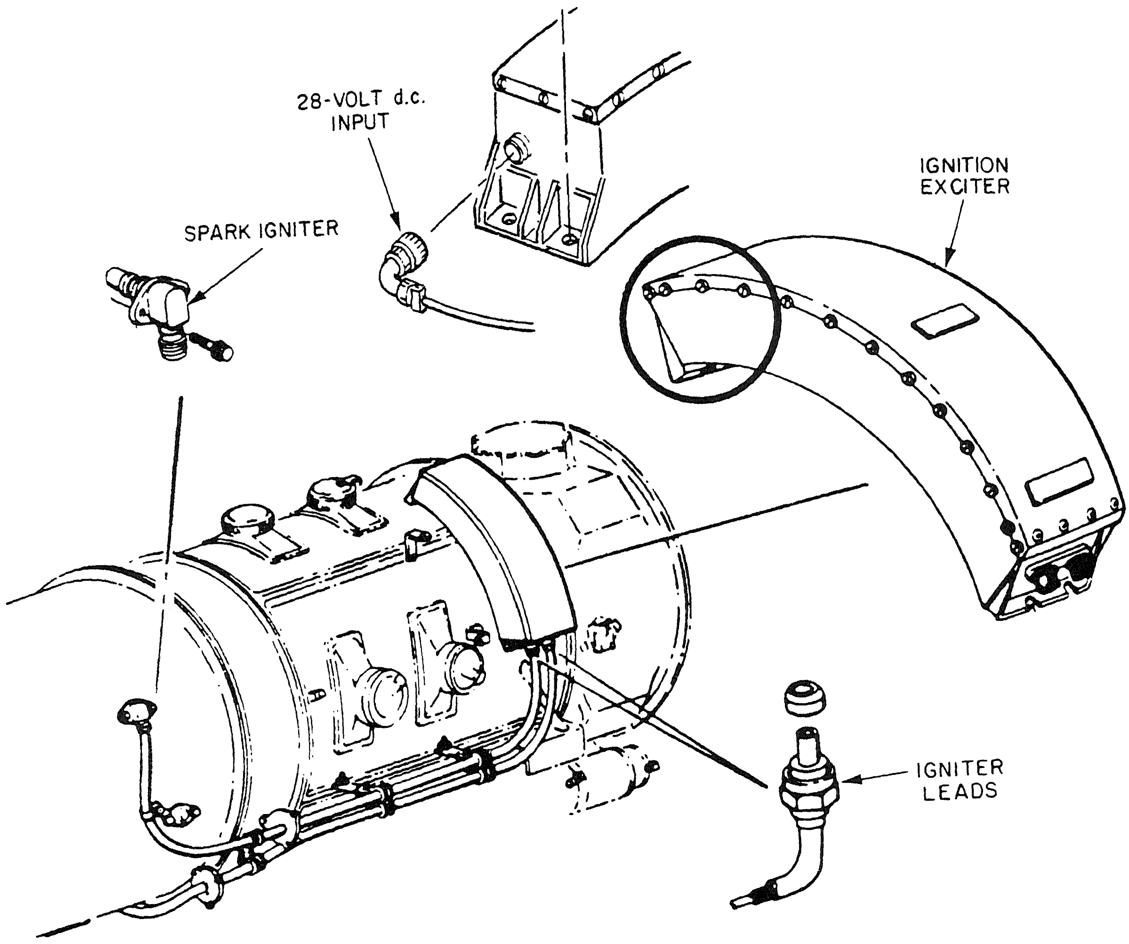

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Figure 8-17.—Igniter system components.

apable of firing two spark igniters at the ame time.

park Igniters

The two spark igniters are mounted in the uter combustion case. One is in the No. 2 can nd one in the No. 5 can. The igniters receive the ectrical output from the ignition exciter. They ischarge this electrical energy during starting to nite the fuel-air mixture in the combustion cans. Two high-voltage leads connect the spark igniters to the ignition exciter.

BLEED AIR SYSTEM

The bleed air systems (figure 8-18) on the Model 104 and Model 139 are nearly identical. The only major difference is found in the 14th-stage bleed air valve. One of the features of the turbine overtemperature protection system (TOPS) is to give a surviving GTGS (assuming a casualty occurs to one GTGS while two units

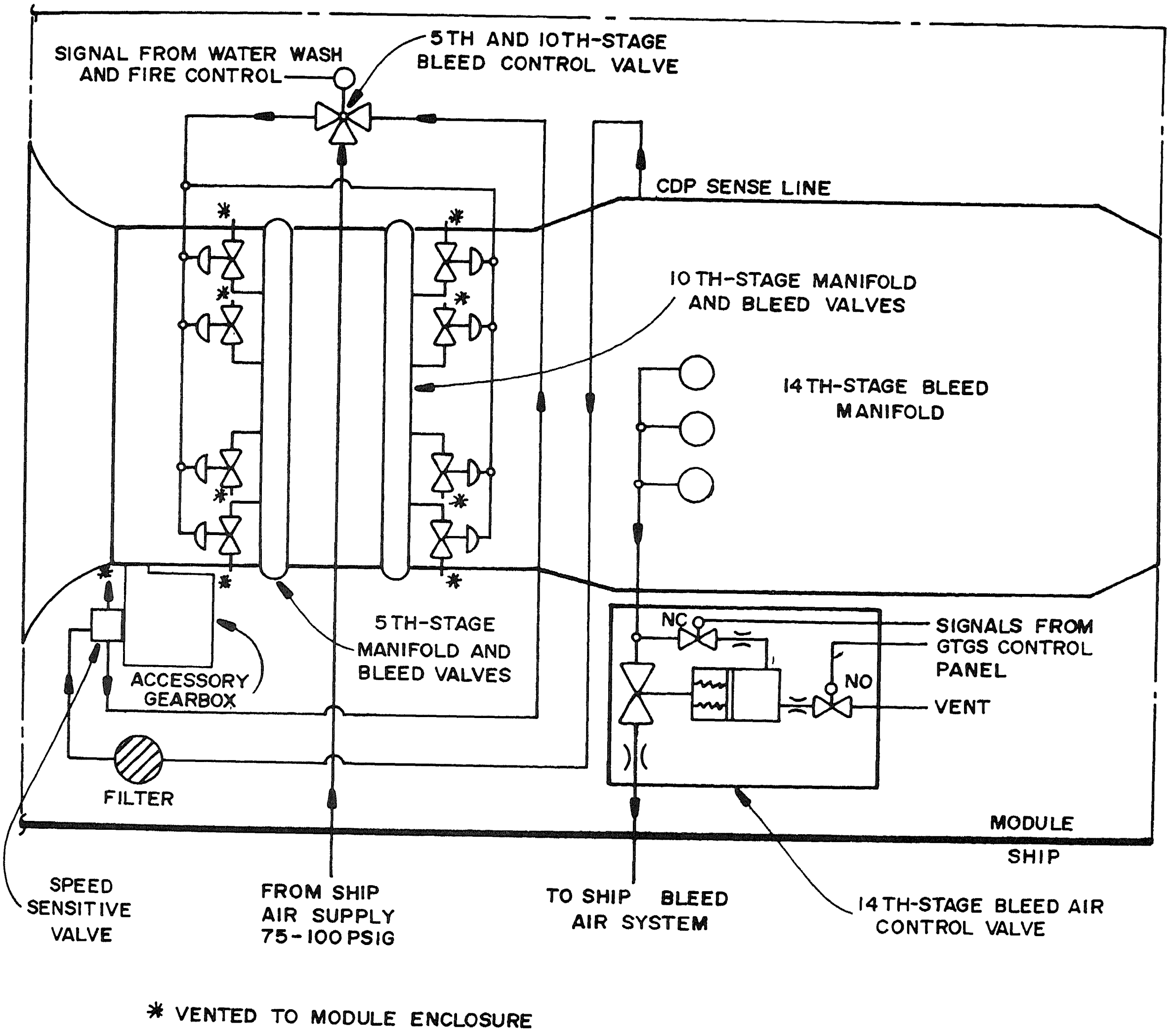

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Figure 8-18.—Allison 501-K17 bleed air systems.

are in parallel) the chance to develop more power quickly. Therefore, a fast-acting 14th-stage bleed air valve is used on the Model 139. Note that use of bleed air drains about 10 percent of the available horsepower from a running GTGS.

This GTGS loss is compensated for by quickly closing (in about 150 milliseconds) the 14th-stage bleed air valve on the surviving GTGS. Thus the engine is able to respond to transient load conditions brought about by failure of one of two GTGSs operated in parallel.

The bleed air system is two independent systems—the 14th-stage system and the 5th- and 10th-stage system. The 5th- and 10th-stage bleed air system unloads the compressor. This reduces the possibility of compressor surge during the starting cycle. The 14th-stage bleed air system extracts air from the compressor for the ship's bleed air system. Airflow up to 2.37 lb/sec at 55 to 60 psig may be extracted. This is about 10 percent of compressor airflow.

Fourteenth-Stage Bleed Air System

Fourteenth-stage compressor discharge air is extracted from ports on the compressor diffuser. It is manifolded and piped to a bleed air control valve and into the ship's bleed air system. The control valve receives a signal from the LOCOP. This signal prevents the engine from being overloaded during combined operation of bleed air and generator loading. If the TIT reaches 1870 °F, the bleed air control valve will close and maintain the TIT in the range of 1850 °F to 1870 °F. A manual switch, 14TH-STAGE BLEED, is located on the LOCOP. It allows you to enable the bleed air control circuit. When this switch is in the ON position, the bleed valve will open at 12,780 rpm. It is then fully automatic with respect to TIT. The 14th-stage bleed air valve will also close when the engine speed drops below 12,780 rpm.

The Model 139 LOCOP bleed air selector switch also has a remote position. When the switch is placed in remote, the control of the 14th-stage bleed air valve is transferred to a control panel in CCS.

Fifth- and Tenth-Stage Bleed Air System

This system has eight pneumatically operated bleed air valves, a speed sensitive valve, a filter, and a solenoid valve. Four bleed air valves are mounted on both the 5th- and the 10th-stage bleed manifolds. These valves are piston-type valves, with 5th- and 10th-stage air pressure on the inboard side of the valve. Either atmospheric pressure or 14th-stage air pressure is on the outboard side. The speed sensitive valve is engine driven. It is mounted on the forward side of the accessory gearbox. The valve has three ports. One port is piped to 14th-stage air. One port is piped to the outboard side of the 5th- and 10th-stage bleed air valves. The third port is vented to atmosphere. During operation at engine speeds below about 12,700 rpm, a pilot valve in the speed sensitive valve blocks 14th-stage air. The outboard side of the 5th- and 10th-stage bleed air valves are vented to atmosphere. Since 5th- and 10th-stage air pressure is greater than atmospheric pressure, the valves open and vent air from the compressor. At engine speeds above about 12,700 rpm, the pilot valve closes the vent port. Fourteenth-stage air is then ported to the outboard side of the bleed air valves. Since 14th-stage air pressure is greater than 5th- and 10th-stage air pressure, the valves close and bleed air is stopped. The filter is located in the 14th-stage air line to the speed sensitive valve. It prevents contaminants in the air from clogging the valve. The solenoid valve is located in the line between the speed sensitive valve and the bleed air valves. It uses ship's service air to hold the 5th- and 10th-stage bleed air valves closed during a fire stop. It also holds the valves closed while water washing the engine.

ENGINE INSTRUMENTATION

Besides the instruments that measure pressure and temperature of the engine's systems and enclosure, several sensors monitor the engine itself. These are the thermocouples, magnetic speed pickup, and the vibration sensor.

The thermocouples are wired in parallel to provide an average TIT signal. This is amplified by the turbine speed temp box in the LOCOP. This signal provides TIT indication and engine emergency shutdown functions. The speed temp

box uses the magnetic speed pickup signal for speed sensing and control during start-up. An alarm and automatic shutdown are provided for an overspeed and underspeed. The speed temp box also transmits a speed and temperature signal for remote display of engine speed and temperature on DDIs. Refer to chapter 3 of this text, Indicating Instruments, for more information about these sensors.

Thermocouple System

There are 18 dual-element, Chromel-Alumel thermocouple probes mounted on the turbine inlet casing. The probes extend into the outlet of the combustion liners at the turbine inlet. Each of the probe elements is independent of the other, thereby providing two independent sampling circuits. The thermocouple probe housing leading edges are air cooled to prolong probe life. To accomplish this, cooling air enters the probe cavity leading edge through a hole below the probe shoulder. It flows through the probe and is discharged through two small openings in the bottom of the probe.

A thermocouple harness assembly has a right and a left section. It is enclosed in channels that are rigidly mounted on the turbine inlet case forward flange. The harness incorporates separate leads for each thermocouple probe. A terminal block serves as the junction for two thermocouple harnesses and the amplifier leads. It has eight terminal connections and four terminals for each of the two harnesses.

Vibration Transducer

Engine vibration is measured by a single displacement type of vibration transducer. It is mounted on the turbine rear bearing support at the 12 o'clock position.

Speed Pickup

Engine speed is measured by a magnetic pickup. This is mounted in the PTO shaft housing over the shaft exciter teeth. Passage of the exciter teeth under the magnetic pickup produces electrical impulses. These impulses are used by the speed temp box for speed sensing. This, in turn, is used for start sequencing, over- and underspeed protection, and monitoring.

POWER TAKE-OFF ASSEMBLY

The PTO assembly has a PTO shaft, shaft adapter, midbearing assembly, housing, and speed sensor pickup (figure 8-19). The assembly

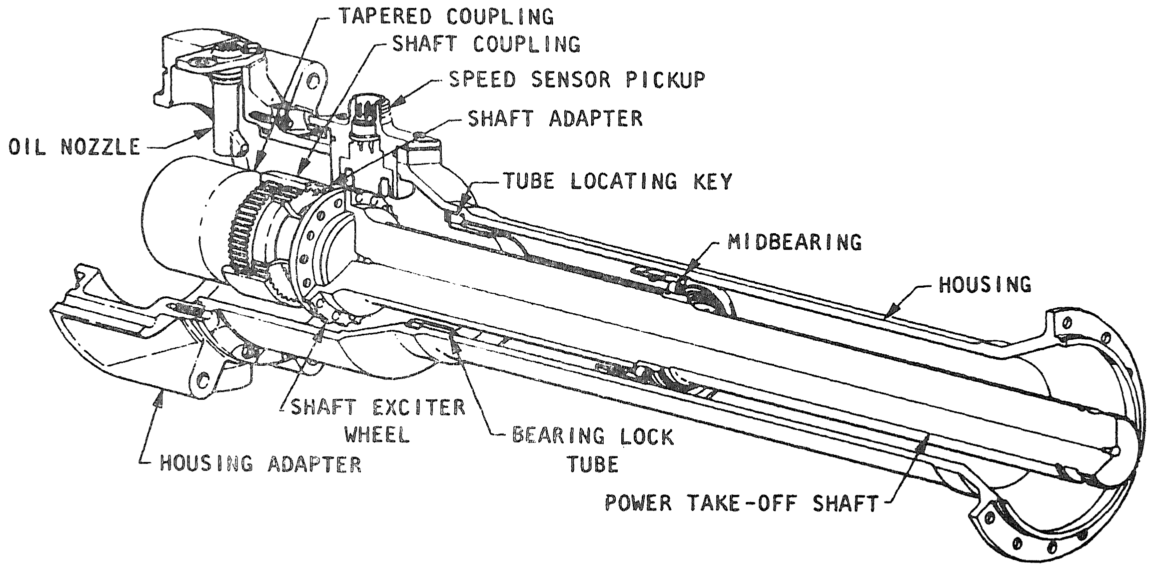

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Figure 8-19.—Power take-off assembly.

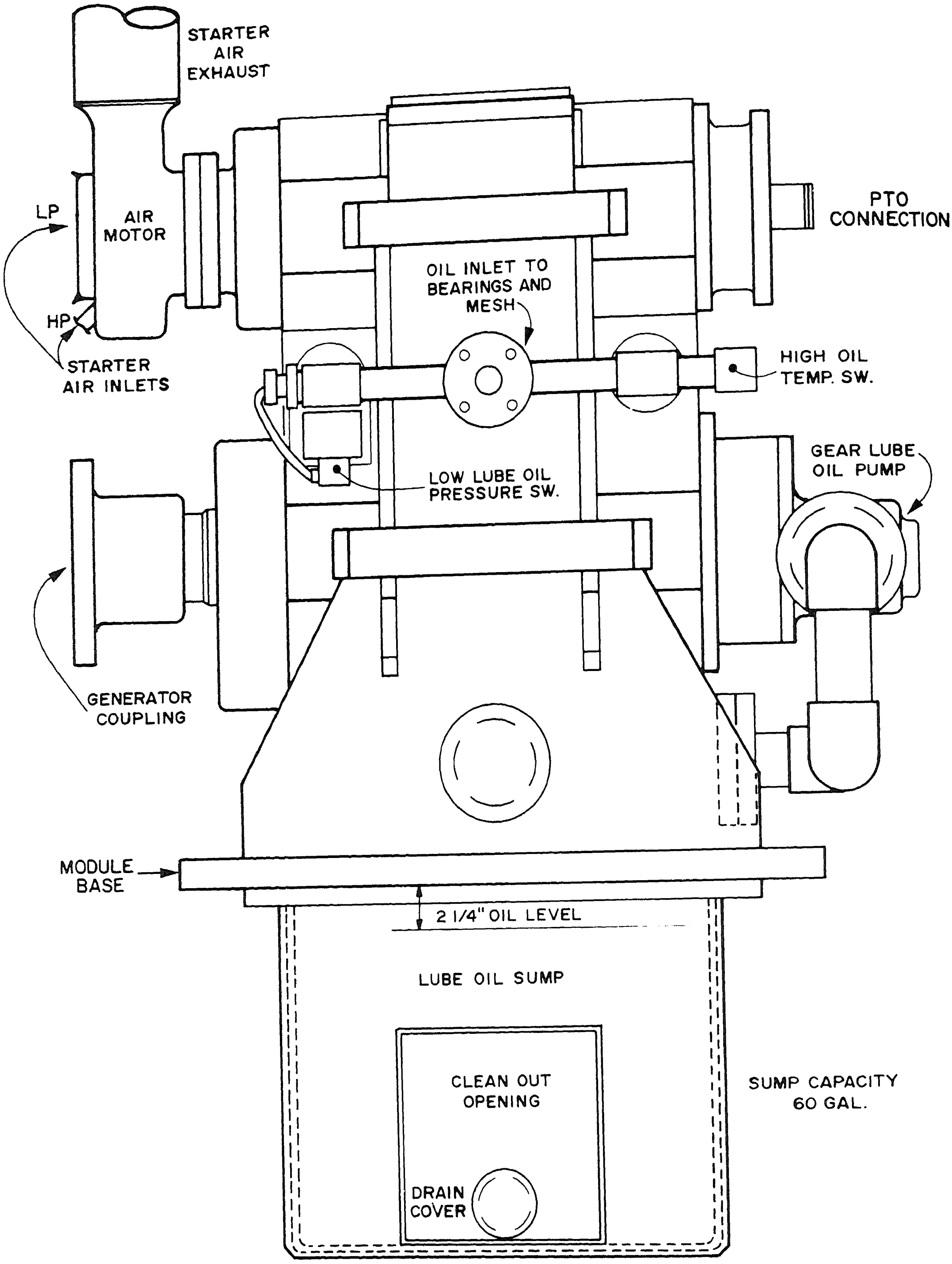

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Figure 8-20.—GTGS reduction gear assembly.

transmits the torque produced by the engine to the reduction gear. It also provides the means to measure the engine speed with a magnetic pickup over the exciter wheel teeth.

Power Take-off Shaft and Adapter

The PTO shaft is a solid steel shaft. It is bolted to the shaft adapter at the forward end and splined to the compressor extension shaft at the aft end. Forty equally spaced teeth are machined on the flange at the forward end of the shaft. These provide excitation for the speed sensor.

Housing

The housing encloses the shaft, supports the forward end of the engine, and contains the midbearing assembly. The housing also provides the mounting for the speed sensor assembly. The midbearing assembly prevents the shaft from whipping.

GTGS REDUCTION GEAR AND STARTER

The reduction gears used to couple the engine to the generator on the two models of GTGSs are identical.

The reduction gear (figure 8-20) is a single reduction, single helical gear type of speed reducer. The reduction ratio is 7.678 to 1. The gear is an over-under, vertically offset, parallel shaft design. It uses a three-piece housing split horizontally at the center lines of the high-speed shaft and the low-speed shaft. The gear elements are supported in sleeve bearings. The starter is mounted on the gear case and drives the high-speed shaft. The oil pump is located at the blind side of the low-speed shaft. The reduction gear is coupled to the generator by a diaphragm-type flexible coupling.

LUBE OIL SYSTEM

The reduction gear lube oil system (figure 8-16) is a wet sump, force-feed system. The sump has a capacity of 60 gallons. It is an integral part of the reduction gear assembly. It also serves as the supply tank for the GT lube oil system. Oil from the sump is picked up by the reduction gear supply pump rated at 40 gpm at 1800 rpm. From the pump, the oil passes through a 25-micron base-mounted filter and through a remotely mounted oil cooler. It is then distributed to the reduction gear, PTO assembly, and to the engine. Pressure at this point is regulated at 25 psig. Oil to the engine and PTO assembly is regulated to 15 psig.

Oil to the PTO assembly is directed by a nozzle onto the shaft coupling. It is then returned by gravity to the sump. The shaft midbearing is lubricated by a spray nozzle on the front of the compressor extension shaft housing. Oil to the reduction gear assembly, 30 gpm at 25 psig, lubricates the reduction gears and bearings. It returns by gravity to the sump.

AIR START SYSTEM

The engine air start system (figure 8-21) has an air turbine starter, a starter exhaust system, and two independent air supply systems. Each system has its own control valve. Air from the LP starter air control valve enters the starter inlet scroll through a 3-inch line. Air from the HP starter air control valve enters the inlet scroll through a 1 1/2-inch line. Exhaust air from the starter is discharged through a 6-inch line into the engine module cooling air duct downstream of the fire damper.

Low-Pressure Air Start System

Air from the ship's bleed air system enters the starter LP air control valve. The control valve is a normally closed, solenoid-operated regulating valve. It regulates airflow to the starter at 1.83 lb/sec at 45 psig.

High-Pressure Air Start System

Air from the HP air flasks enters the starter HP control valve. The control valve is a normally closed, solenoid-operated regulating valve. It regulates airflow to the starter at 2.75 lb/sec at 450 ± 50 psig. A bypass line with an orifice and a pilot valve provides for smooth engagement of the starter teeth. An HP start signal will cause the pilot valve to open. This allows air to flow through the orifice to the starter at less than 50 psig to engage the starter teeth. After about

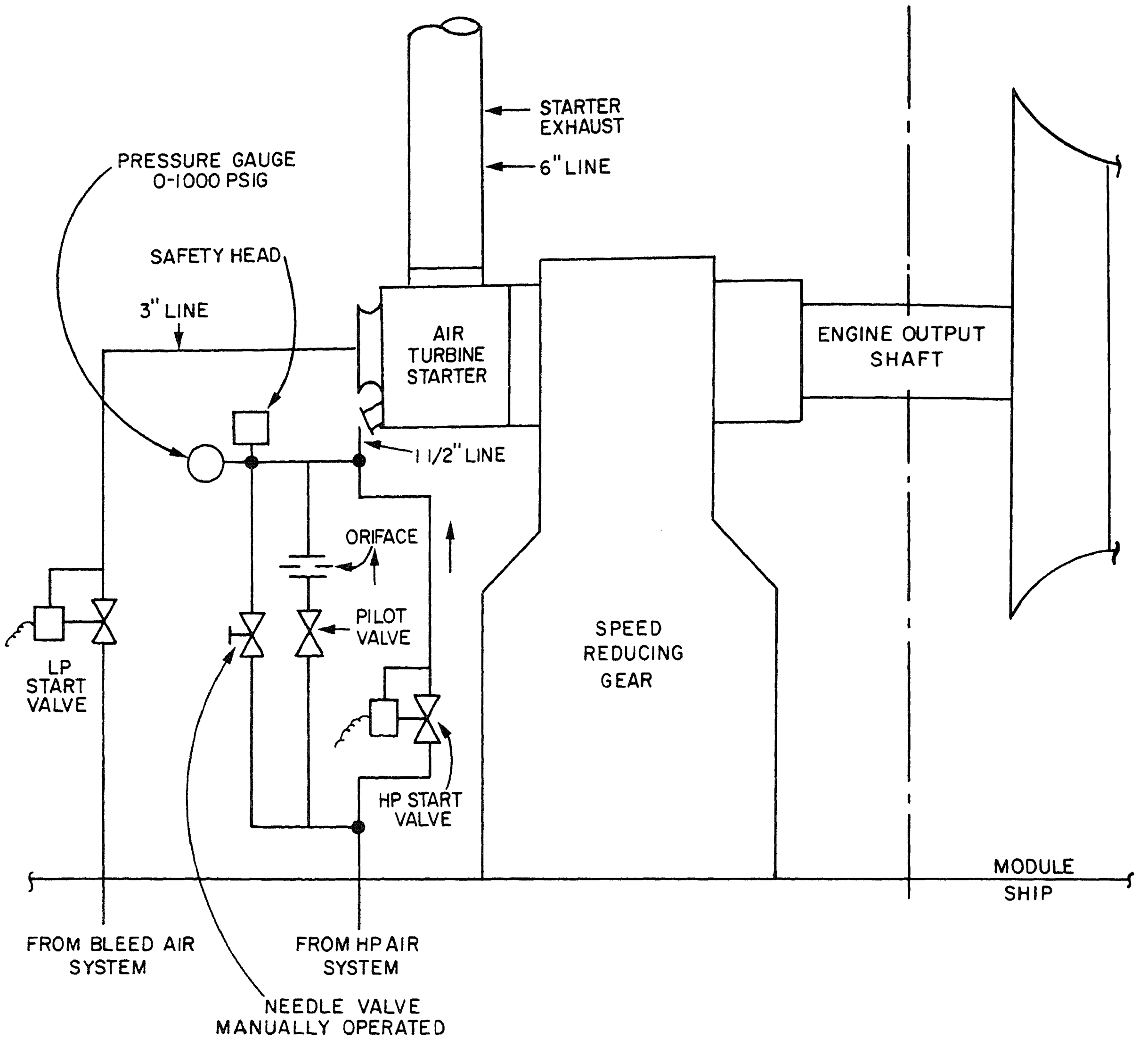

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Figure 8-21.—GTGS air start system.

one-quarter second, the pilot valve will cause the air control valve to open. Full pressure (about 500 psig) is then applied to the starter for rotation. A manual needle bypass valve is provided for manual HP starting.

Air Starter Motor

The Bendix air turbine starter is mounted on the generator side of the reduction gear high speed input shaft. It drives the engine through the reduction gear during the start cycle.

ALTERNATING CURRENT GENERATOR AND VOLTAGE REGULATOR

Two different a.c. generators are powered by the Allison 501-K17 engine. The Model 104 GTGS is a 2000-kW, 3200-amp unit whereas the Model 139 GTGS is a 2500-kW, 4000-amp unit. Both generators output 450-volt, 60-Hz, 3-phase a.c. at a 0.8 power factor with an 1800 rpm input. Both units are totally enclosed, salient pole, two

bearing construction. Each unit has an air cooler mounted above it to cool the generator. An independent lube oil system using 2190 TEP lube oil provides lubrication for the generator bearings.

MODEL 104 GENERATOR

The Model 104 generator has eight major components. The following eight items are keyed to the components shown in figure 8-22.

1. Stator assembly of four-pole, four-circuit, delta connection
2. Rotor assembly with four salient poles
3. Front and rear end bracket assemblies
4. Front and rear bearing assemblies
5. Rotor slip ring brush assembly
6. Overhung permanent magnet alternator and lube oil pump assembly
7. Air cooler assembly
8. Stator terminal/connection box

The field rectifier assembly of the exciter/voltage regulator is also mounted in the airstream within the generator enclosure.

The generator may be overloaded for a short time as follows:

2120 kW 0.8 PF (2650 kVA)
3400 amperes 30 minutes

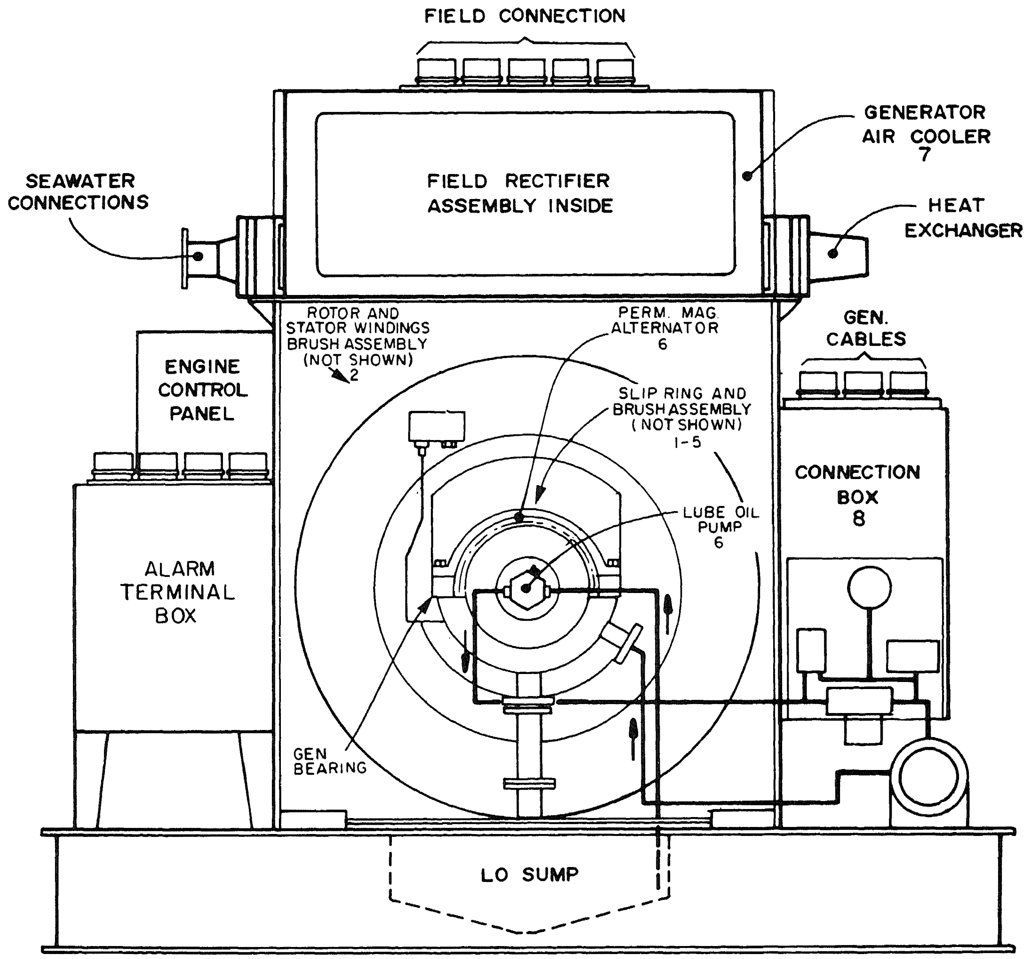

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Figure 8-22.—Model 104 generator.

1875 kW 0.5 PF (3750 kVA)
4810 amperes 2 minutes

MODEL 139 GENERATOR

The Model 139 generator has eight major components. The following eight items are keyed to the components shown in figure 8-23.

1. Stator assembly of four-pole, four-circuit, delta connection
2. Rotor assembly with four salient poles
3. Front and rear end bracket assemblies
4. Front and rear bearing assemblies
5. Brushless exciter assembly
6. Permanent magnet alternator and lube oil pump assembly
7. Air cooler assembly
8. Stator terminal/connection box

The brushless exciter assembly of the generator is connected to the airstream within the generator enclosure by ductwork.

The generator may be overloaded for a short time as follows:

2750 kW 0.8 PF (3437 kVA)
4410 amperes 30 minutes

2344 kW 0.5 PF (4688 kVA)
6014 amperes 2 minutes

AIR COOLER

The housing air cooler assembly is mounted in the generator above the generator frame. It is

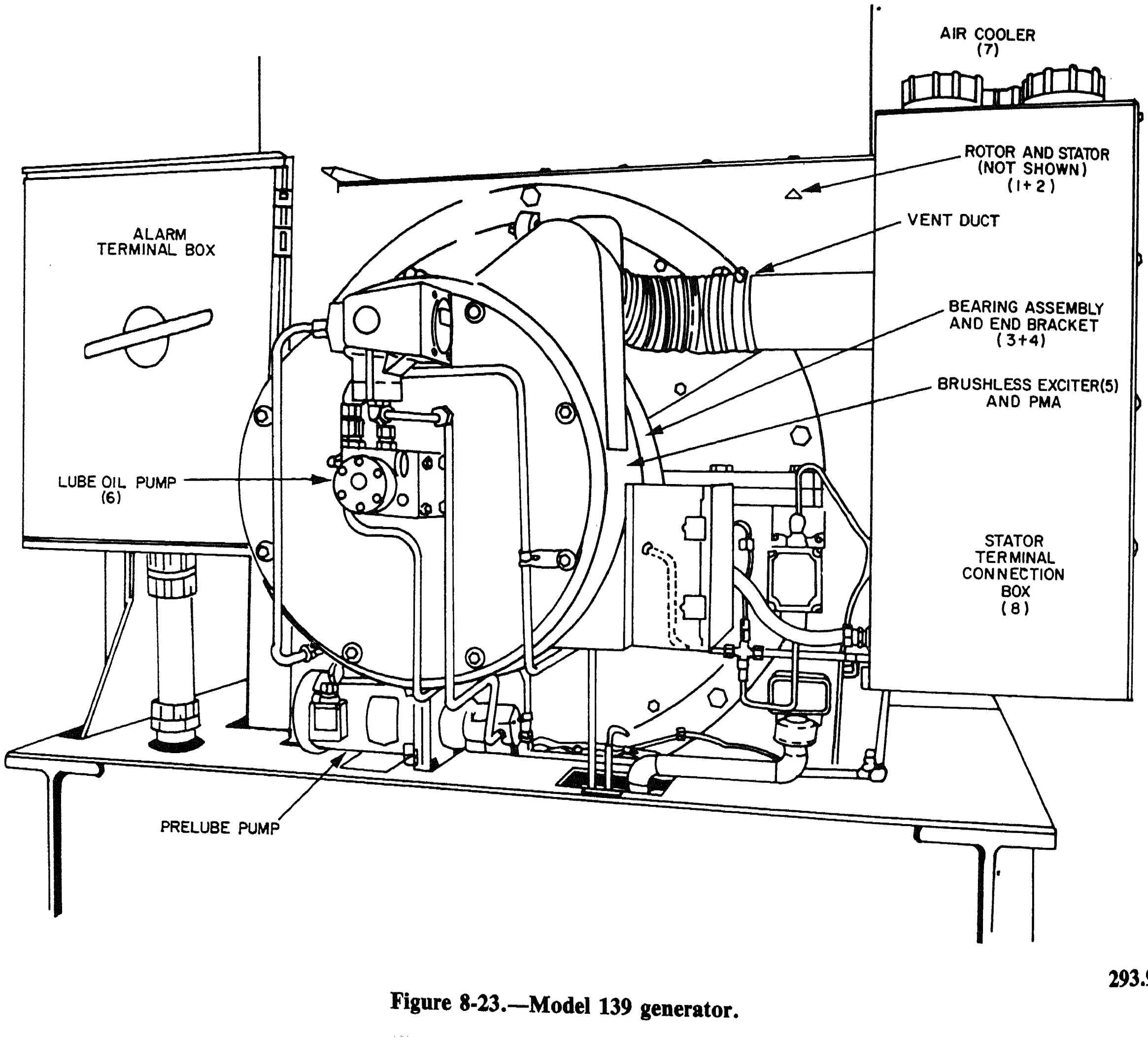

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Figure 8-23.—Model 139 generator.

an air-to-water, double-tube, extended fin-type heat exchanger. It has a core assembly and two water boxes with four zinc anode pencils. The pencils are replaceable units. They are inspected periodically using maintenance procedures. Flanged connections on one water box provide for seawater inlet and outlets. The tubes of the core have a plain inner tube and an internally fluted outer tube. The outer tube carries the aluminum cooling fins. In a leaking inner tube, the outer tube provides a water passage to the leakage compartment at each end of the core. Each leakage compartment has a telltale space vent and a telltale drain.

LUBE OIL SYSTEM

The generator lube oil system (figure 8-24) is independent of the gas turbine/reduction gear

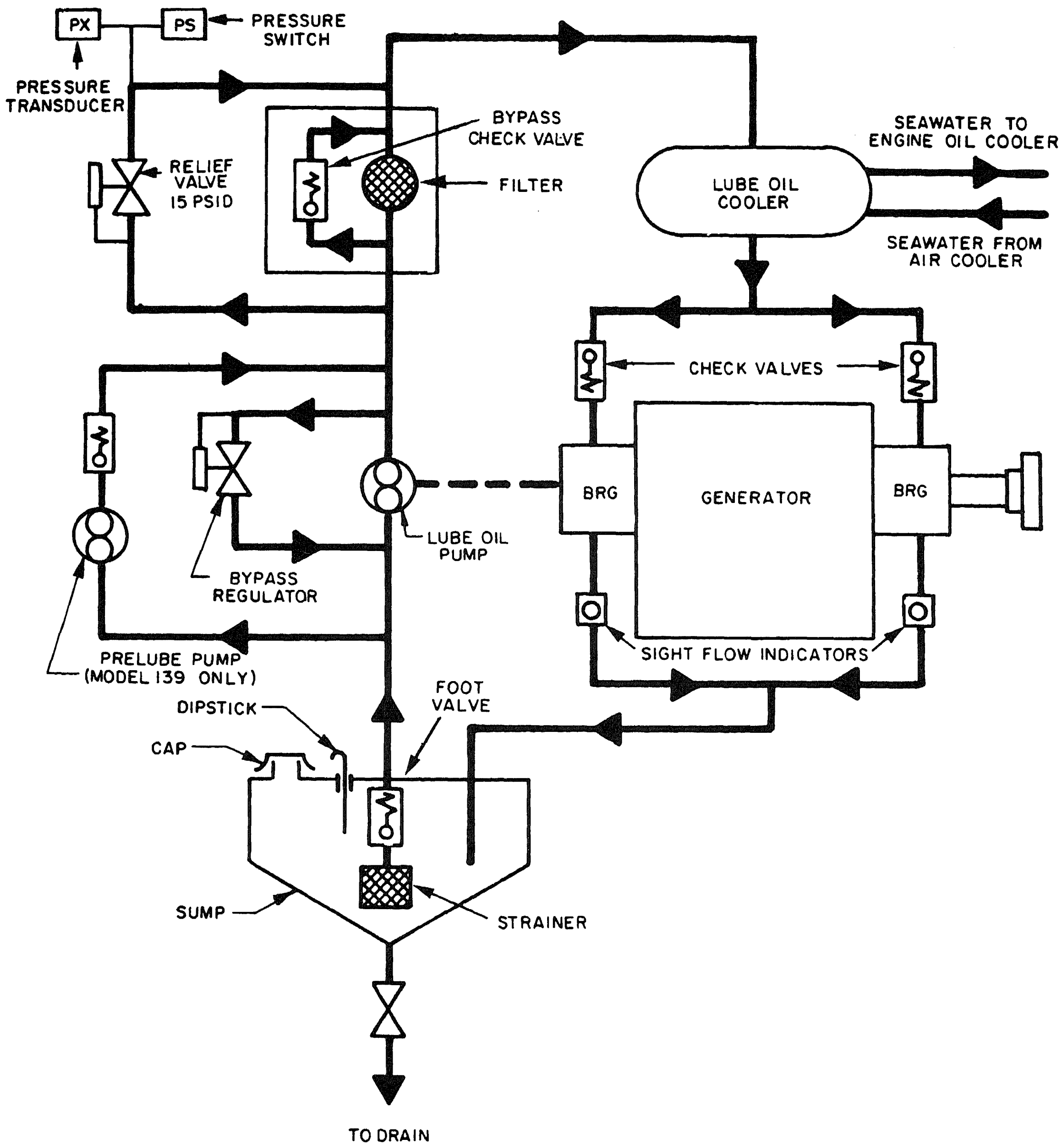

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Figure 8-24.—Generator lube oil system.

lube oil system. The generator system uses mineral oil (2190 TEP). It force-feeds the two bearings with 3 gpm at 12 to 15 psig pressure. Oil is taken from the sump tank in the GTGS base by a pump mounted on the permanent magnet alternator shaft. The oil is then passed through a 25-micron filter and the base-mounted cooler before reaching the sleeve bearings. Gravity flow through a sight glass returns the oil to the sump. On the Model 139 a prelube pump is installed to provide the initial lubrication to the generator upon start-up.

SPACE HEATERS

Electric heater elements are mounted at the bottom of the generator. They prevent the condensation of moisture when the generator is secured or on standby. Four 120-volt, 250-watt, tubular, finned heaters are mounted crosswise under the stator. They are spaced to distribute heat along the length of the stator. A heater control switch with an indicator lamp is mounted on the control section of the switchboard. An interlock on the generator circuit breaker automatically disconnects the space heaters when the breaker is closed.

TEMPERATURE MONITORING

Nine copper RTDs are embedded in the generator stator winding slots. The three-wire lead of each RTD is brought to an internal terminal board. A rotary selector switch and a temperature indicator are mounted on the LOCOP for monitoring six stator winding temperatures. The three remaining RTDs serve as spares.

A tip-sensitive RTD is embedded in the babbitt of each generator bearing. A terminal assembly, connector, and straight plug are provided for each RTD. A rotary selector switch and temperature indicator, mounted on the LOCOP, selects and monitors the two bearing temperatures. Both stator and generator bearing RTD outputs are signal conditioned at the LOCOP. They are transmitted to the engineering control and surveillance system (ECSS) for monitoring.

VOLTAGE REGULATION

The two GTGSs use different voltage regulators. The major components of the voltage regulators are mounted in the generator or in the generator control unit (GCU). The GCU is mounted in the same area as the switchboard.

Model 104 Voltage Regulation

The following four items are the major components of the Model 104 voltage regulator (figure 8-25).

1. Static exciter/voltage regulator assembly deck mounted near the associated switchboard
2. Field rectifier assembly mounted in the generator enclosure air path
3. Motor-driven rheostat mounted on the associated switchboard for manual voltage control
4. Mode select rotary switch mounted on the associated switchboard

The GCU provides generator field excitation at about 100 amperes at 150 volts d.c. at full load. Voltage control is in automatic or manual modes. Figure 8-25 is the GCU functional diagram.

GENERATOR FIELD EXCITATION.—Excitation power for the generator field is supplied by the generator output. It is controlled by a three-phase magnetic amplifier. Different values of d.c. flowing in a control winding provide different levels of saturation in the magnetic amplifier. This controls the output of the magnetic amplifier to the generator field.

Another source of field excitation comes from three current transformers (CTs). This is rectified by a three-phase, full-wave bridge in the field rectifier assembly. Since the source of field excitation for the magnetic amplifier comes from the generator output, a short circuit on the system will cause the voltage to collapse. This results in a loss of excitation voltage. The excitation source from the CTs can supply enough excitation to the generator field under short circuit conditions to keep the generator output at a minimum 320 percent of rated current. In this way the overcurrent devices can sense the short circuit. They can trip the generator breaker to clear the fault.

On initial start-up of the generator, the magnetic amplifier has little or no excitation voltage. To assure that the generator voltage will build up, another source of excitation must be used. Excitation is supplied by the permanent magnet alternator (PMA) on the generator shaft extension. It is rectified through a three-phase full-wave bridge. The output voltage of this excitation source is less than the normal output of

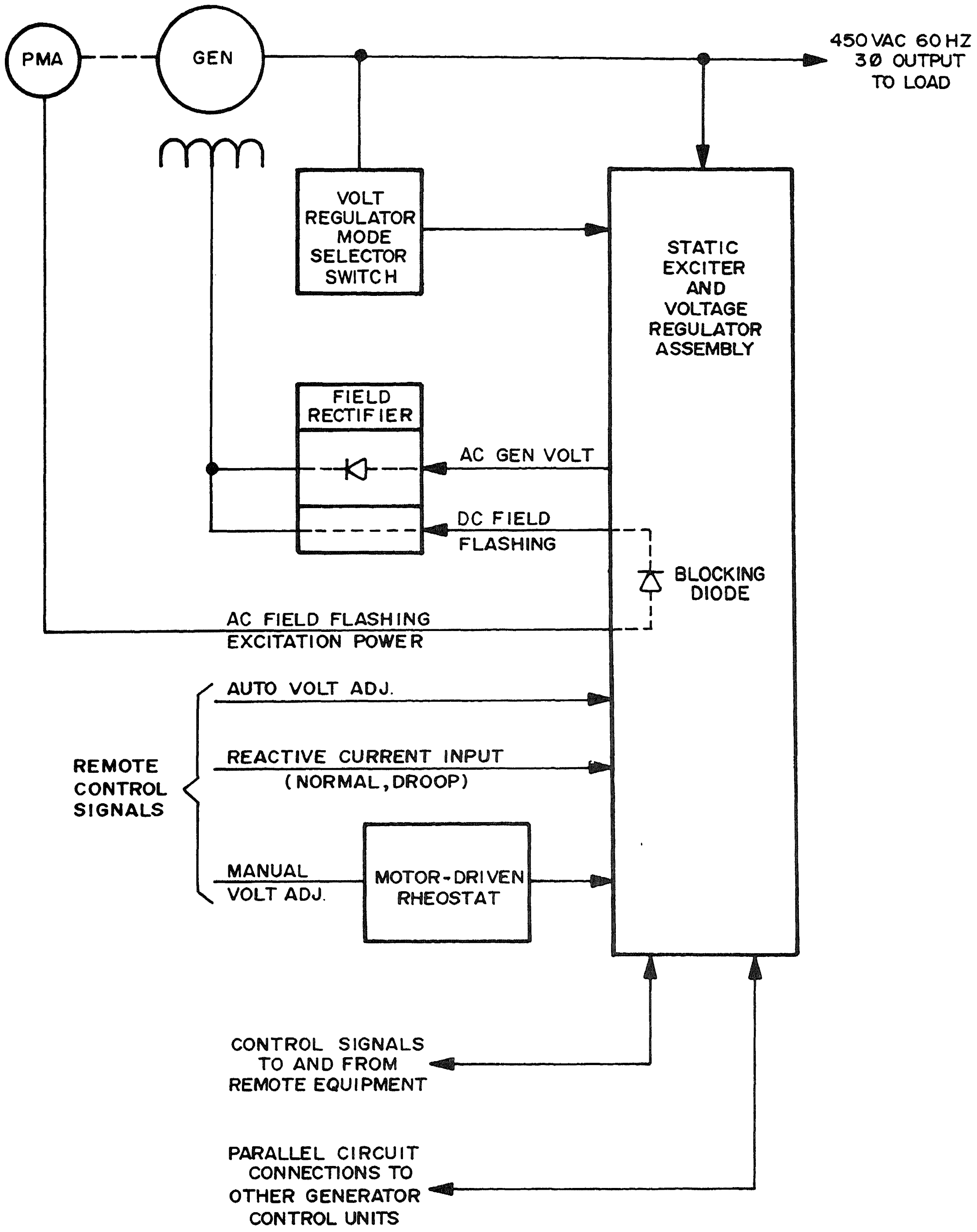

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Figure 8-25.—Model 104 voltage regulator functional diagram.

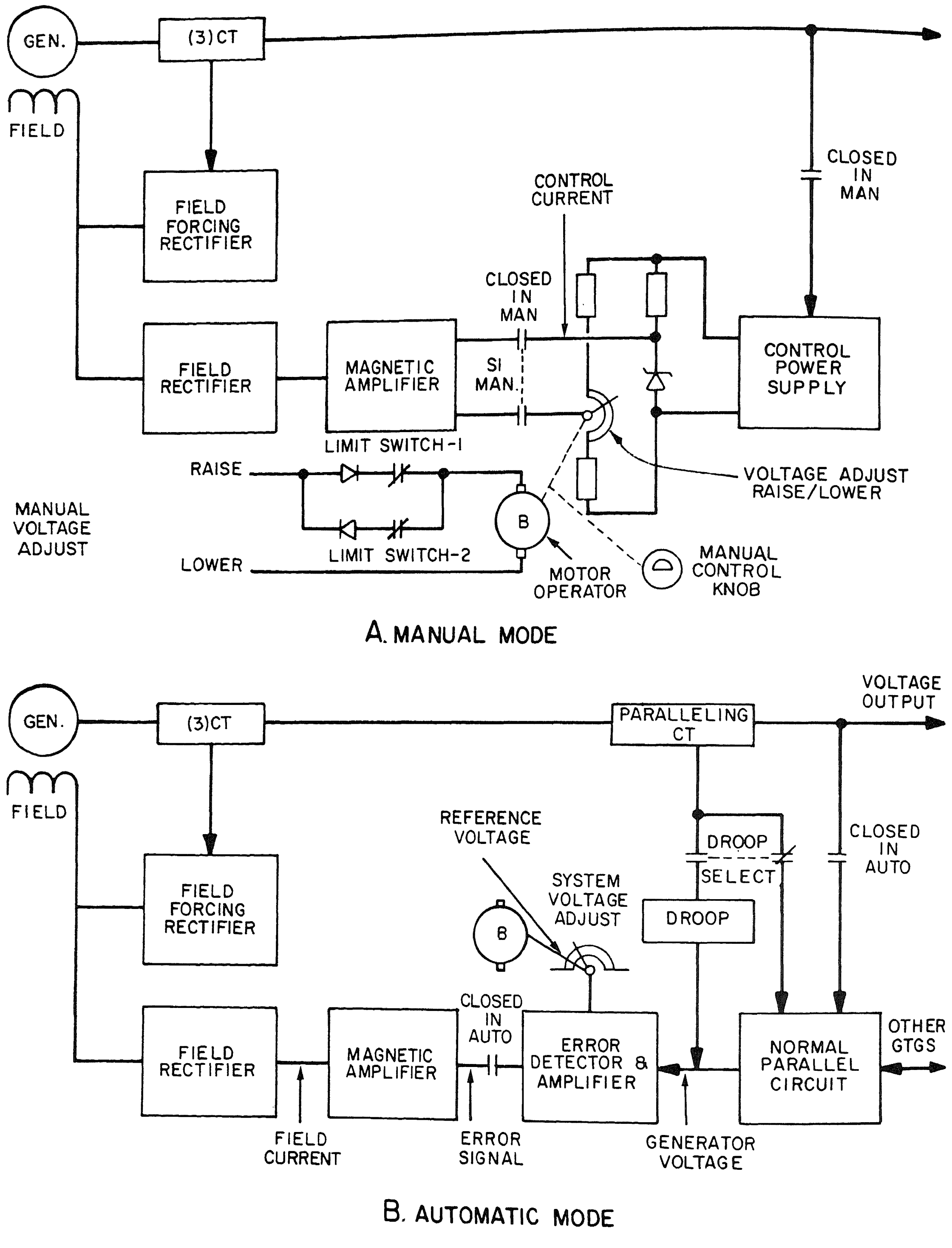

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Figure 8-26.—Model 104 manual and automatic voltage regulation.

the magnetic amplifier at 450-volt generator output. Therefore, it is automatically removed by a blocking diode once the magnetic amplifier output takes over. This function is called field flashing.

Under manual operation (figure 8-26, item A), the source of control current for the magnetic amplifier is an internal power supply. You can adjust the control current from the switchboard by the MANUAL MODE VOLT ADJ knob or the GEN VOLTAGE RAISE-LOWER switch (with the VOLT REG MODE switch in the MAN position). With the EPCC in manual control, the control current may also be varied through the VOLT LOWER-OFF-RAISE switch at the EPCC.

In automatic operation (figure 8-26, item B), the voltage regulator output supplies control current to the magnetic amplifier fields. An internal motor-driven rheostat sets the required voltage. Control for this motor is from the switchboard for local operation and from the EPCC for remote operation.

VOLTAGE REGULATOR.—The voltage regulator in auto operation compares generator voltage with a reference voltage to provide an error signal (figure 8-26, item B). This error signal is amplified and applied to the magnetic amplifier control winding. This changes the output of the magnetic amplifier. This, in turn, provides field current to set the output voltage of the generator. The reference voltage is adjustable through the motor-driven rheostat in the static exciter/voltage regulator assembly.

A line current signal is brought in from the three paralleling CTs to the field forcing rectifier. This provides two functions in automatic mode.

1. When an individual generator is on line, this current signal acts to compensate for load changes. When load increases, this signal will call for an increase in excitation. This relieves the voltage regulator of having to make the entire correction with its error signal. This load compensation increases the accuracy of voltage regulation.
2. When two generators are operating in parallel, their voltages are equal. Therefore, any adjustments in the excitation of individual machines can only change the power factor of both machines. This creates circulating reactive currents between machines. In this case, the current signal brought in from the paralleling CT will help regulate the division of reactive line current. This reduces circulating current between machines.

Model 139 Voltage Regulation

The major components of the Model 139 voltage regulator (figure 8-27) consist of the following:

1. Two voltage regulator assemblies (normal and standby), mounted in the GCU enclosure
2. Motor-operated rheostat for auto voltage regulation, mounted in the GCU enclosure
3. Brushless exciter assembly, mounted on the generator
4. Permanent magnet alternator (PMA), mounted on the generator
5. Auto Voltage Control RAISE-LOWER switch, mounted in associated switchboard
6. Motor-operated variac for manual voltage adjustment, mounted in the associated switchboard
7. Mode select

The GCU provides brushless exciter field excitation and voltage control in the automatic control modes.

GENERATOR FIELD EXCITATION.—Main generator field excitation is supplied by a brushless exciter assembly. The brushless exciter assembly has three main parts: stator, rotor, and rectifier assembly. The rotor and rectifier assembly are attached to the generator shaft. They turn inside the stator that is attached to the generator frame. The operation of the exciter is similar to that of any a.c. generator. The exception is the rotor and stator functions have been reversed. When d.c. is passed through the exciter field winding, lines of flux are created that pass through the air gap. This creates a three-phase a.c. output from the rotor. This three-phase a.c. is rectified to d.c. by the rectifier assembly. It is then conducted through the generator field. An advantage of using this brushless exciter over the brush slip ring type of generator is the greatly reduced maintenance.

VOLTAGE REGULATOR.—Two solid-state voltage regulators (normal and standby) control the exciter field in normal automatic operation (figure 8-28). Indicator lights on the face of the

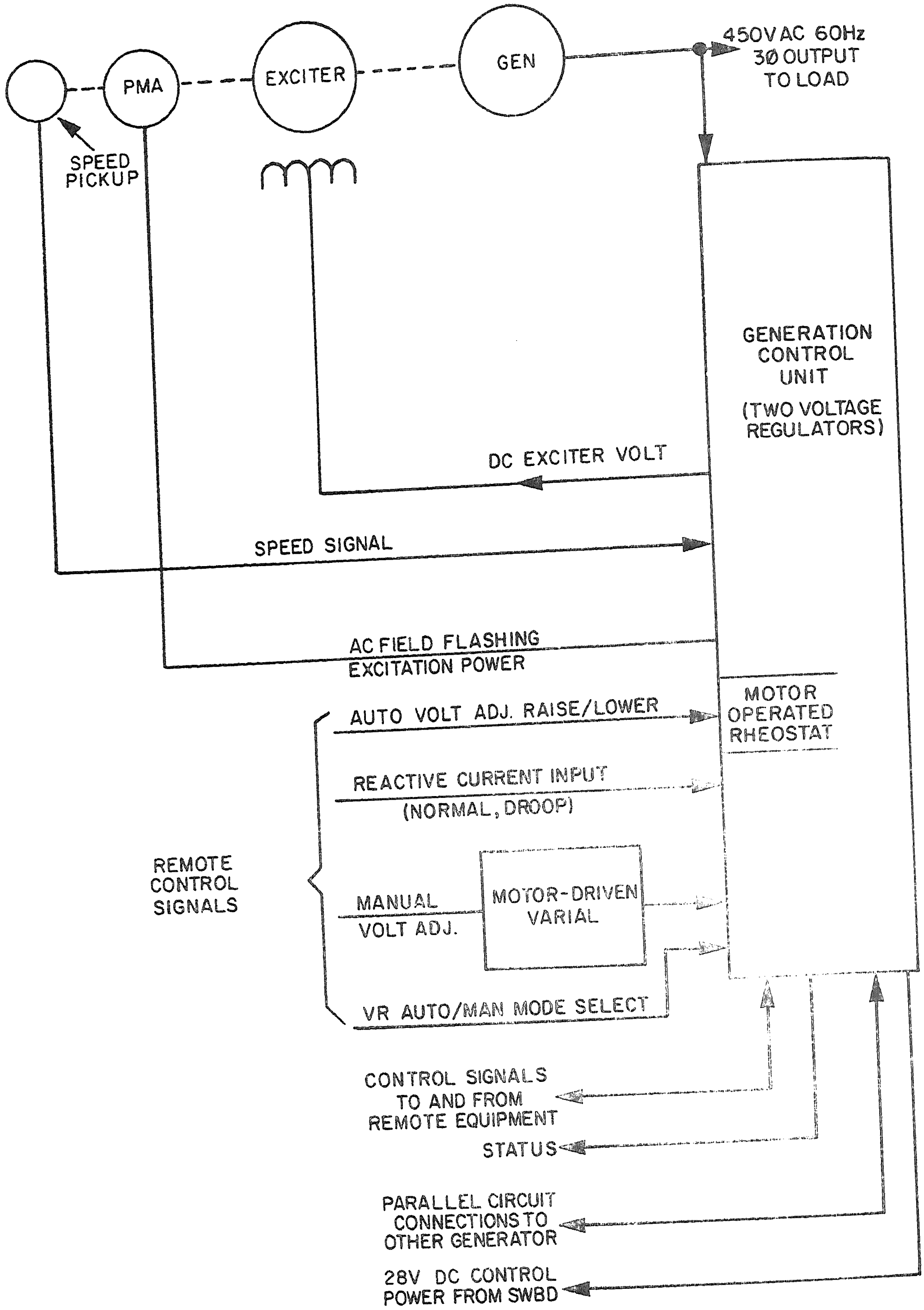

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Figure 8-27.—Model 139 voltage regulator functional diagram.

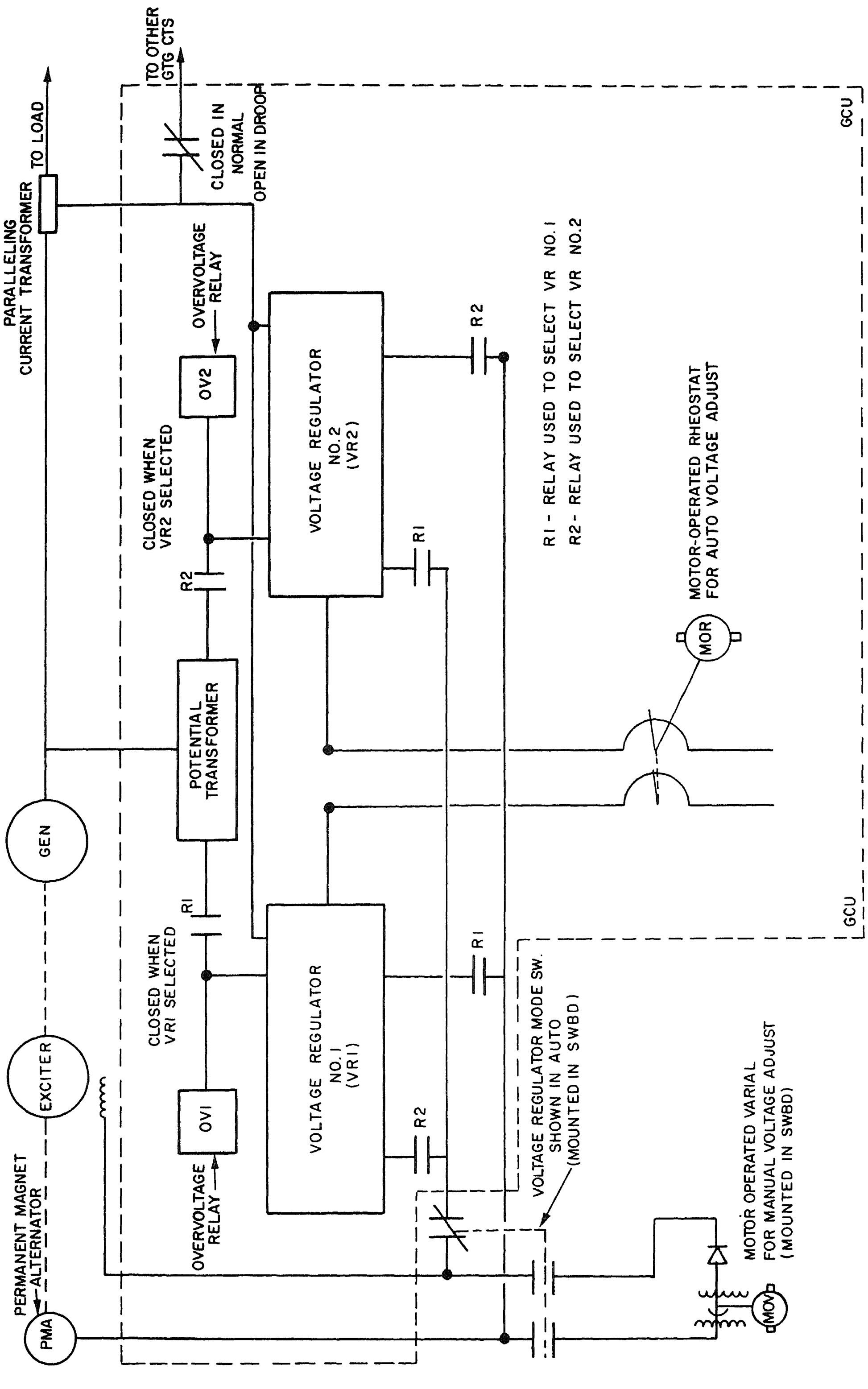

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Figure 8-28.—Model 139 voltage regulator.

GCU depict which regulator is in use. Overvoltage relays are provided to automatically switch regulators if a regulator fails. This prevents an overvoltage condition. An indicating light on the face of the GCU will illuminate when a regulator fails. A RESET pushbutton is provided on the face of the GCU. When depressed, it will return control to the (normal) regulator. It also extinguishes the regulator failed light. Manual or automatic control may be selected at the switchboard by the VOLT REG MODE-OFF/AUTO/MANUAL control. The regulators receive their power from the generator output through potential transformers. Thus, on initial start-up of the generator in automatic mode, the voltage regulator will have little or no excitation voltage. To assure that the generator voltage will build up, excitation is obtained from the PMA. A relay internal to the regulator will divert power from the PMA to the generator field until voltage has risen about 350 volts (75 percent of rated). Then, the relay will switch excitation control over to the regulator.

The source of regulator power is the generator output. Therefore, a short circuit on the system will cause the voltage to collapse. This results in a loss of excitation voltage. If a short circuit occurs, a relay internal to the regulator will transfer excitation from the regulator to the PMA. This is done if the voltage drops below about 225 volts. This will allow the generator to supply enough current to activate overcurrent devices. It will also trip the generator breaker to clear the fault.

In manual operation, the generator excitation is controlled by the motor-operated variac mounted in the switchboard. Power is received from the PMA. It is scaled by the variac, then rectified and conducted to the exciter field (figure 8-29). You can make adjustments at the switchboard by turning the Manual Mode Volt Adjuster knob (with the VOLT REG MODE switch in the MAN position). When in the manual mode, you may make voltage adjustments from the EPCC. Operation of the Voltage Raise/Lower control on the EPCC activates the motor-operated variac. In the manual mode, generator voltage will decrease with load unless field excitation is increased. Thus when operating in the manual mode, observe generator operation carefully.

In automatic operation (figure 8-28), the voltage regulator output supplies control current

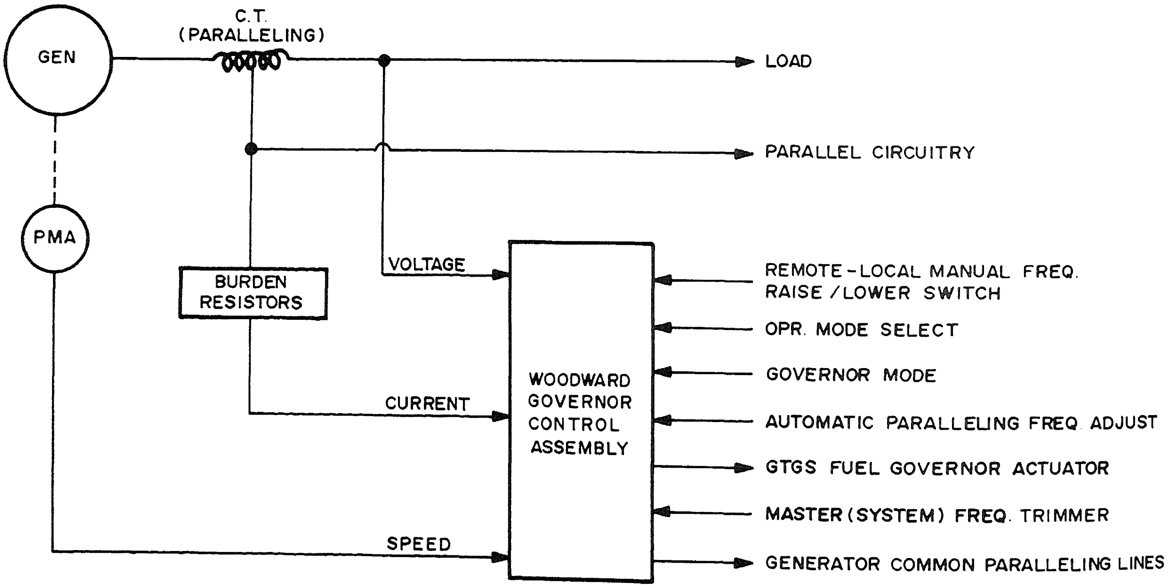

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Figure 8-29.—Woodward 2301 governor interface diagram.

to the exciter fields. The GCU internal motor-driven rheostat sets the required voltage. Control of this motor is from the switchboard Voltage Raise/Lower control for local operation and the EPCC for remote operation. When in automatic, the MASTER VOLTAGE ADJ located on the EPCC will also operate the motor-operated rheostat in the GCU. It changes the reference for the voltage regulator. This command will be parallel to the GCUs. It will raise or lower the reference to all regulators.

A line current signal is brought in from the paralleling CT. It provides two functions in automatic mode.

1. When two generators are operating in parallel, their voltages are equal. Therefore, any adjustments in the excitation of individual machines can only change the power factor of both machines. This creates circulating reactive currents between machines. In this case, the current signal brought in from the paralleling CT will help regulate the division of reactive line current. This reduces circulating current between machines.
2. When two generators are operating in parallel and in droop mode, the reactive current signal will produce a fixed droop in the voltage output of a generator. If an individual generator takes on an increased share of reactive current, its voltage will droop more. This, in turn, will tend to transfer some of that reactive current to the other machine. If both machines have equal voltage droop, they will tend to share reactive currents at various loads. But it is not self-regulating.

SPEED GOVERNING

The Allison 501-K17 is a constant speed engine. That is to say, it will maintain the proper speed (13,821 engine rpm) to output a steady 60 Hz. Dependable 60-Hz power is required to keep electronics and motors operating at their peak output. The Allison 501-K17 uses an electrohydraulic governor to maintain this constant speed. Two different electronic control systems are used on the two models of GTGSs. The Model 104 GTGS uses the Woodward 2301 control system, whereas the Model 139 GTGS uses the Woodward 9900-320 control system. Both Model GTGSs use the Woodward EGB-2P electro-hydraulic actuator.

Both systems normally operate on the EG. The EG will maintain the frequency set by the operator. Once the frequency is set and the load is balanced between GTGSs in parallel, the governor system will maintain the set frequency and load balance. If failure of the EG control occurs, a mechanical flyweight governor will regulate the engine speed. The mechanical governor is set slightly higher than the EG. It will maintain a frequency of about 62 Hz. This mechanical governor prevents overspeed of the engine during an EG failure. It is set by a screw adjustment on the actuator.

2301 GOVERNOR SYSTEM (MODEL 104)

The engine speed governor on the Model 104 GTGS is the Woodward 2301 electrohydraulic control system. It has a backup centrifugal governor override. Two major components within the system are an electronic control unit and an electrohydraulic actuator. The control unit is mounted in the GCU. The actuator is mounted on the GTG. The control unit is a solid-state electronic package. It processes input commands and feedback signals to generate a signal to position the actuator. The actuator positions its output shaft in response to the control signal. This shaft controls the engine's LFV through a mechanical linkage. If the engine speed increases to a preset limit because of a failure in the electronic control, then the centrifugal governor section of the actuator will automatically assume control of the output shaft. Engine speed will then be controlled at a point slightly above the normal operating speed.

The governor system has two basic operating modes, NORMAL (isochronous) and DROOP. The isochronous mode provides constant speed operation, regardless of load. When generators are operated in parallel and in the isochronous mode, the governor system maintains a constant speed. It also controls the load division between paralleled generators. The isochronous mode is selected when the EPCC selector or the switchboard selector is in the NORMAL position. The load sharing function is automatically enabled

when a generator operating in the NORMAL mode is paralleled with another generator.

In the droop mode, the governor system regulates engine speed. The speed will decrease slightly, however, with an increase in load. Sometimes the generator is paralleled with a constant frequency bus (such as shore power) while in the droop mode. In this case, the governor cannot control speed since it is held constant by the bus frequency. Instead, it will control the load carried by the generator. In this way, the droop mode provides load control of a generator paralleled with shore power. It also can unload a generator paralleled with another GTGS without disturbing system frequency. When the selector is in the DROOP position, droop mode is selected at the EPCC or the switchboard.

The operating point of the governor is set by a motor-operated potentiometer. It is located at the electronic control unit. The individual frequency adjust controls at the EPCC or the switchboard are used to adjust the potentiometer. These controls adjust the position of the motor-operated potentiometer to a higher or lower position. If generators are operated in parallel from the EPCC, with the system frequency controls enabled, the motor-operated potentiometer returns to a calibrated 60-Hz position. You can make adjustments by using the SYSTEM FREQUENCY ADJUST control at the EPCC. This control will position a master frequency trimmer in the EPCC. It sends equal adjust signals directly to each generator's electronic control unit. Therefore, the frequency of the bus can be changed without disturbing the load balance between operating units. During automatic paralleling operations, the automatic paralleling device (APD) will adjust the oncoming generator for synchronization. This adjust signal is also a direct input into the electronic control unit. It is in effect only during automatic paralleling conditioning. Figure 8-29 is a governor interface diagram.

Electronic Control Unit

The electronic control unit of the 2301 governor system is modular in design. It has eight major subunits. The following terms are a list of these subunits and are keyed to figure 8-30, a functional diagram of the 2301 governor.

1. Summing amplifier
2. Load sensor
3. Frequency sensor
4. Two power supplies
5. Motor-operated potentiometer
6. Accessory box
7. Two filters

The motor-operated potentiometer (1) supplies a reference to the amplifier. When the electric plant operates in manual, manual permissive, or droop mode, frequency adjust commands will cause the motor to rotate in the raise or lower direction. This changes the reference correspondingly. When operating in the automatic mode, the motor automatically drives to and remains at 60 Hz. This position is established by the motor's limit switches. External adjustments to the governor system are done by additional inputs to the amplifier. These inputs come from either the master frequency trimmer (2) or the APD (3).

The amplifier (4) provides the current to the actuator (5). This current is varied in response to the inputs to the amplifier. This includes the reference, frequency feedback, and load sensing. Input changes because of load, speed, or reference cause the amplifier current to reposition the actuator output shaft. This increases or decreases fuel flow. Amplifier current then stablizes at a new setting that satisfies all inputs. The amplifier is reverse acting. That is, the larger the input (error signal), the smaller the output current to the actuator. The actuator output shaft is designed to work so a decrease in current causes it to drive the LFV toward the maximum fuel position. If the amplifier fails and the current goes to zero, the actuator will be positioned in the maximum fuel position. (The centrifugal governor assumes control if engine speed increases to the preset limit.)

The PMA input to the control unit provides voltage for the two power supplies (6) and a frequency feedback signal to the frequency sensor (7). One power supply feeds the amplifier; the second provides power for the motor-operated potentiometer. The frequency sensor converts the PMA output (8) (about 120 volts a.c. at 420 Hz)

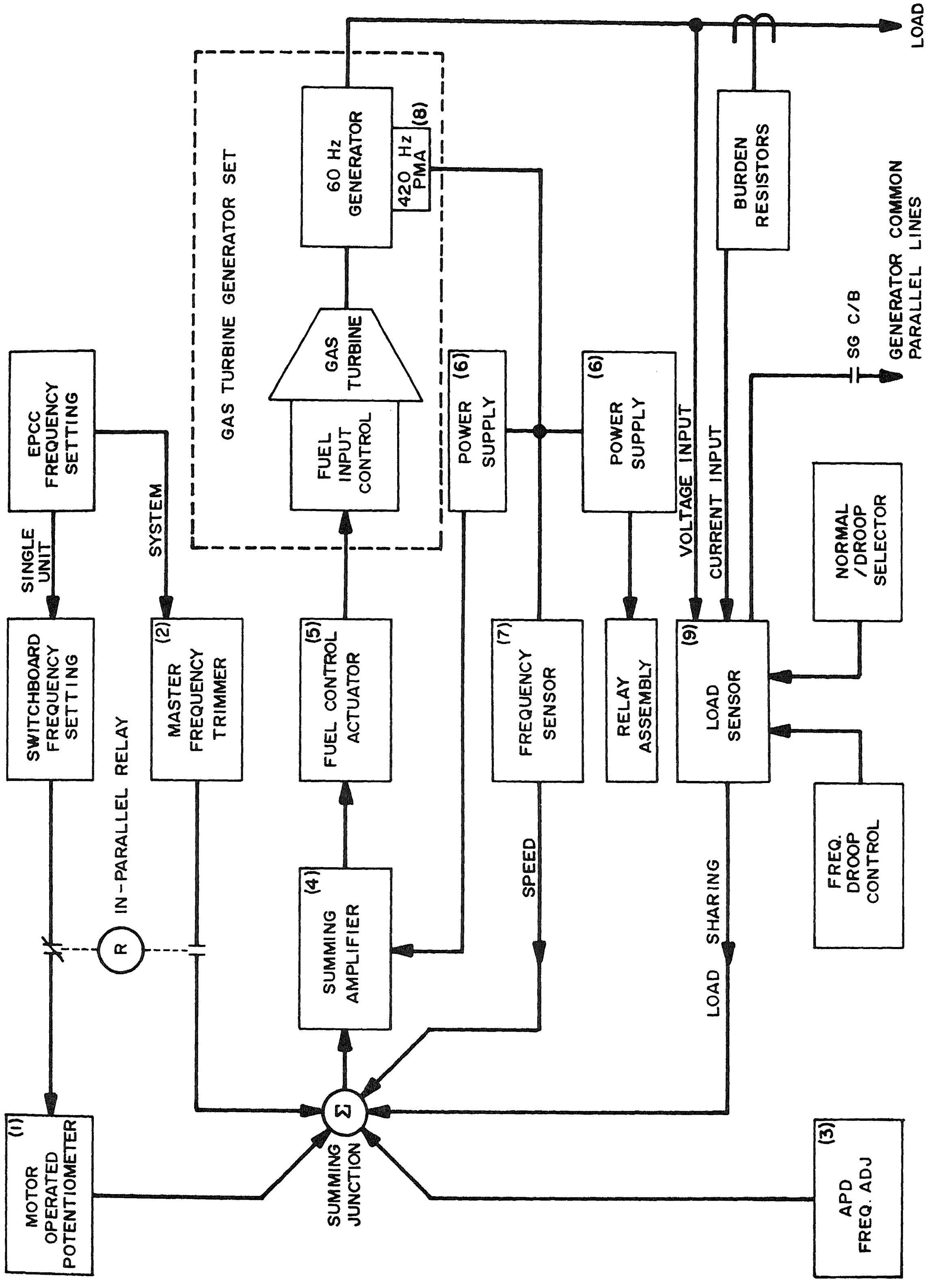

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Figure 8-30.—2301 governor functional diagram.

to a proportional d.c. voltage. This is used for the frequency feedback input to the amplifier.

The load sensor module (9) controls load sharing in parallel isochronous operation. It is used to generate the droop characteristics during droop operation. Power generated by the generator is measured by transformers. They supply voltage to a bridge circuit. For load sharing, the bridges of each paralleled generator are connected so an unbalance because of uneven loads causes an input to each governor amplifier. This forces proportional fuel adjustments until the loads are balanced between the two units. This also balances the bridge circuits. The amplifier input is again returned to algebraic zero volts d.c. Sudden shifts in load demand cause pulses to be developed in the load sensor. This upsets the algebraic zero voltage of the governor amplifier. This results in quicker response to load changes. Polarity of the pulse is also sensed to determine the direction of load changes.

During droop mode some of the load sensor output opposes the action of the amplifier speed reference. The input to the amplifier will be decreased by an amount proportional to load, resulting in droop.

If the generator is not paralleled with another source, this droop will result in a decrease in frequency. The decrease is proportional to the increase in load. If the generator is paralleled with an infinite bus (such as shore power), droop provides load control. When paralleled with an infinite bus, the speed of the machine is held constant by the bus. The governor system, therefore, cannot control speed. Any attempt to increase or decrease speed will only result in an increase or decrease in load. Without the droop characteristics, the governor system would attempt to adjust the frequency to satisfy the reference exactly. Thus, it will cause the load to increase beyond generator capacity or decrease until the flow of power reverses. The droop input, however, will modify the speed reference. The governor will reach a stable operating point even though the frequency does not match the reference. This operating point is set by the speed reference and droop input (since frequency is constant). It determines the load on the generator. Under this condition, the load on the generator will remain constant for any reference setting.

Centrifugal Governor

The independent centrifugal governor system is used as a backup control system. It backs up the electronic control unit of the Woodward governor system. The centrifugal governor speeder spring device takes over control if (1) the electronic control unit fails and (2) the engine speed increases due to the actuator positioning itself for full speed failure mode. This is at about 62 Hz (depending on load) or the equivalent speed of about 14,300 rpm. This is 480 rpm above the 60-Hz speed of 13,821 rpm. The centrifugal governor is part of the hydraulic actuator assembly.

Master Frequency Trimmer

A master frequency trimmer in the EPCC provides frequency control to any two or all three generators when operating in parallel. You may use the EPCC panel SYSTEM FREQ RAISE/LOWER switch to demand a change of frequency for the paralleled units. This control inputs 115 volts a.c. into a reversible motorized potentiometer assembly. The potentiometer output is a d.c. signal. Its amplitude is proportional to the correction demanded in the generator output frequency. The polarity dictates the direction of change. This potentiometer assembly is located at the EPCC and is shown on figure 8-30.

9900-320 GOVERNOR SYSTEM (MODEL 139)

The engine speed governor on the Model 139 GTGS is the Woodward 9900-320 electrohydraulic control system. It also uses a backup centrifugal governor override. There are eight components within the system. These components are shown on figure 8-31, an interface diagram of the 9900-320 governor. They are an electronic fuel control, an LFV with an LVDT, an EG-B2P actuator, an Allison speed and temperature module, a CIT sensor, a magnetic pickup, a speed phase matching (SPM) synchronizer, and a master frequency trimmer. Following is a list of these

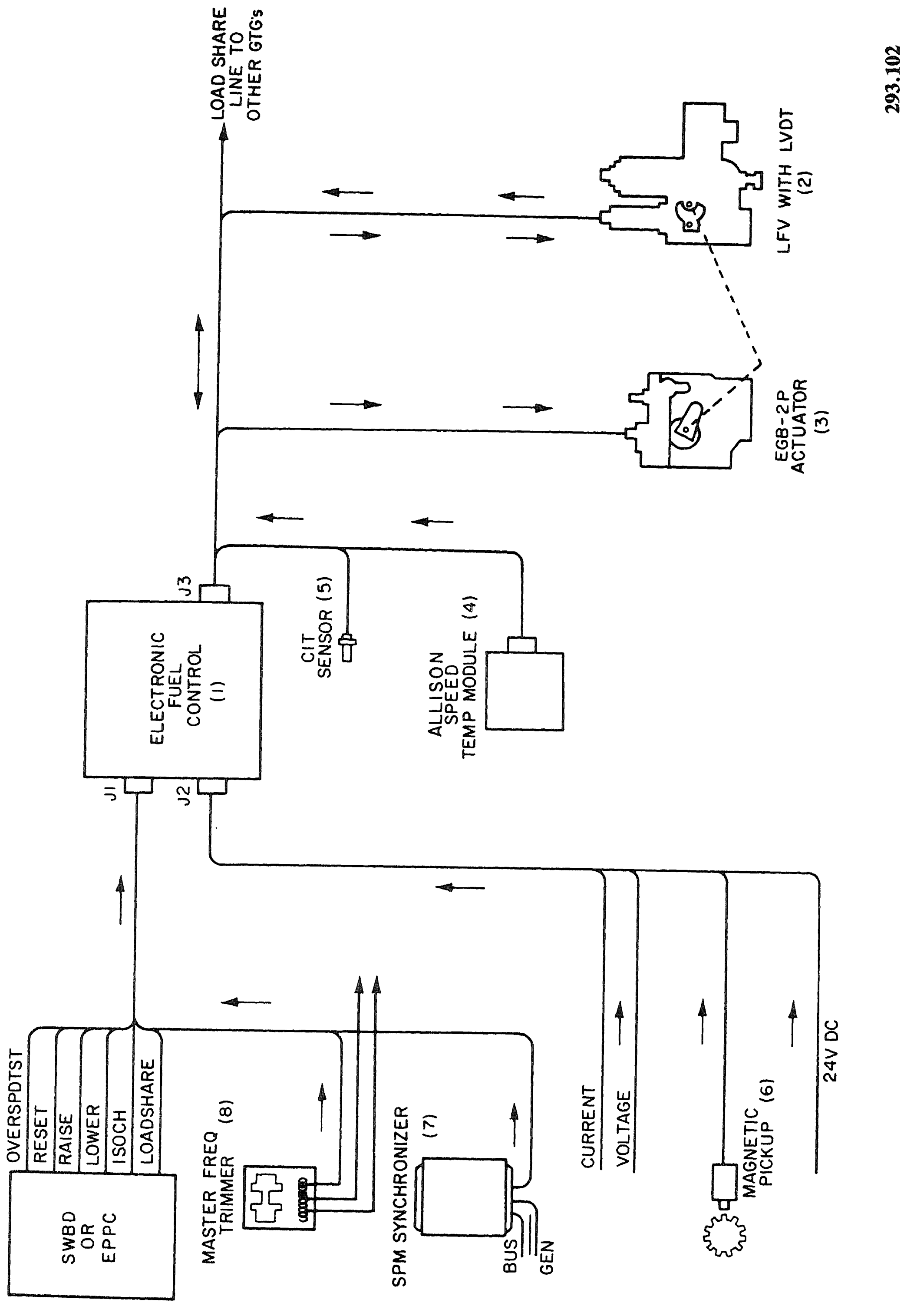

Figure 8-31.—9900-320 governor interface diagram.

eight components and a brief description of their functions. The items are keyed to figure 8-31.

1. The electronic fuel control regulates fuel during turbine lightoff, temperature control, acceleration, and 60-Hz power generation.
2. The LFV with LVDT meters the fuel to the engine.
3. The EG-B2P actuator positions the LFV with LVDT.
4. The Allison speed and temperature module monitors the TIT. It supplies a signal to the electronic fuel control. This is for the start fuel schedule and for maximum temperature control.
5. The CIT sensor monitors the ambient air temperature. It applies the signal to the speed correction and acceleration temperature reference circuits.
6. The magnetic pickup senses turbine speed as an a.c. pulse signal with a frequency proportional to the speed of the turbine.
7. The SPM compares the phase of the generator with that of the bus. If an error is sensed, a signal is applied to the fuel control unit. Then the generator phase angle will be brought in phase with the bus.
8. The master frequency trimmer is used when the turbine is in load sharing. It changes power system frequency without changing the load division between engines.

The control unit is a solid-state electronic package. It has input commands and feedback signals. They generate a signal to position the actuator. The actuator positions its output shaft by responding to the control signal. This shaft controls the engine's LFV with LVDT through a mechanical linkage. The LVDT is mechanically linked to the internal metering sleeve. This sleeve meters fuel flow to the engine. If the engine speed increases to a preset limit because of a failure in the electronic control, the centrifugal governor section of the actuator will automatically control the output shaft. Engine speed will be controlled at a point above the normal operating speed.

Like the 2301 governor system, the 9900-320 governor system has two basic operating modes, NORMAL (isochronous) and DROOP. Refer back to the section on the 2301 governor which describes the operating modes.

Electronic Control Unit

The control unit is modular in design and has nine major modules: a load sensor, isolation, speed reference, speed channel, power supply, fuel limiter, temperature channel, final driver, and motherboard. These modules are found in the governor box in the GCU. Figure 8-32 (a foldout at the end of this chapter) is a functional diagram of the governor control. It shows the three major control functions separated by broken lines. These functions are speed control, temperature control, and fuel limiting.

The following paragraphs describe the operation of the electronic fuel control to the board level. The module titles are descriptive of their major function.

LOAD SENSOR MODULE.—This module uses inputs from the generator voltage and current transformers. Each phase is monitored for current and voltage by potential transformers and CTs. This determines the load. Each CT develops a voltage across a burden resistor, proportional to generator current. The signal representing the load on the three phases is summed in the load sensor.

The current in all three phases is corrected for power factor and summed in the load sensor module. This provides a signal proportional to the load on the bus. A load gain potentiometer is located within the load sensor. It determines the percentage of the load that this generator handles in a load sharing situation with other generators.

The droop potentiometer within the load sensor determines the percentage of speed change. This is used when the turbine generator is operating in droop mode. The effect of droop is a decrease in speed setting for an increase in load. A portion of the load gain voltage is applied to the speed channel as a droop signal.

When the turbine is in isochronous mode, the load pulse amplifier provides a speed error correction signal in advance of the normal speed error signal. This improves the short-term transient response of the controller. The output of the load pulse amplifier is applied to the speed control summing point in droop mode. It is applied to the load matching circuit in isochronous mode.

In the load sharing mode, a bridge within the load matching circuit is connected in parallel with the bridges in other controls. When the load on the generator varies, an error signal is generated by the load matching circuit. This adjusts the load carried by the generator. LED indicators show the selection of isochronous and load sharing modes.

ISOLATION MODULE.—The isolation module provides buffering of the Woodward governor master frequency trimmer and Woodward governor SPM synchronizer signals. Also, the discrete logic signals for the overspeed test, reset to 60 Hz, raise, lower, isochronous, and load sharing control are buffered through isolators on this module.

SPEED REFERENCE MODULE.—The speed reference module generates the d.c. reference signal used by the speed control module. The reference values are selected by inputs from the switchboard or the EPCC. When the command is made to change frequency, a digital counter within the speed reference starts to count. It counts in an increasing or decreasing direction toward the new reference level. The counting process continues until the input command to change frequency is present. It continues until the new reference level is reached. The output of the counter is applied to a digital-to-analog converter. The converter changes the digital output of the counter to the output analog speed reference voltage. The speed reference module indicators show when it is at the reset, lower, or upper limits. They also show when they are moving.

SPEED CHANNEL MODULE.—The speed channel module maintains turbine speed at the value selected by the operator. A magnetic pickup (MPU) provides an a.c. signal that is proportional to turbine speed. The frequency sensor circuits convert the MPU signal to a proportional d.c. turbine speed signal. The speed control compares the actual turbine speed signal with the reference signal. The speed control amplifiers then generate a voltage signal to maintain or correct turbine speed. The speed control loop has the following inputs.

- Master frequency trimmer
- Synchronizer
- Frequency sensor
- Speed reference signal
- Load sensor

These speed error signals are input to the summing point. The stability amplifier applies the summed signal to the speed control gain amplifier.

The control amplifiers provide proper transient response of the turbine. The stability amplifiers control the time required to recover from a transient. The gain amplifiers control the amplitude of the transient. Correct adjustment is achieved when the time and off speed are both minimized without turbine instability.

The output for the speed control circuit is applied to the low-signal select (LSS) bus. The LSS bus has diode inputs from the speed, temperature, LSS bus maximum limit clamp, and the fuel filter control amplifiers. The bus allows the lowest signal input to dominate the bus. The output of the LSS bus is applied to the input of the high-signal select (HSS) bus. A speed control feedback signal is used so the control amplifier can anticipate control of the LSS bus. This provides smooth, bumpless transition between control channels without excessive overshoot.

POWER SUPPLY MODULE.—The power supply module provides isolated d.c. power for the control circuits. The power supply converts 28 volts d.c. to +12 volts d.c. and +R and −R precision reference voltages for use by the control circuits. The +12 volts d.c. and −12 volts d.c. voltages power the control electronics. The +R and −R voltages are reference voltages where precise voltages are required. The d.c. voltages are distributed to the modules by the motherboard. During maintenance on the governor system, a jumper wire must be used between two designated test points. This enables the LEDs on the circuit cards to illuminate.

FUEL LIMITER MODULE.—The fuel limiter module contains the circuits required during turbine start-up and acceleration. The start fuel schedule circuit controls the fuel flow to the turbine during start-up. It monitors three signals from the turbine—first TIT, second CIT, and third N_1 (speed voltage). CIT and N_1 together

produce corrected speed. Corrected speed is the voltage from the speed frequency sensor corrected by the CIT temperature. Speed correction results in increased fuel as CIT decreases. Start fuel is decreased as a function of TIT. More fuel is required for start-up than for acceleration at correct temperatures.

The output from the start fuel schedule is applied to the HSS bus. The HSS bus is a comparator circuit. It allows the highest signal applied to the bus to pass. The other input to the HSS bus is the fuel limiter circuit. The fuel limiter limits the maximum amount of fuel to the turbine as a function of speed. At rated or isochronous speed, fuel is limited by the mechanical stop on the fuel valve. When turbine speed is in the low-speed range, the fuel limiter signal is less than the start fuel schedule. So the fuel limiter signal is not selected by the HSS bus. The output from the HSS bus is applied to the fuel limiter amplifier. This amplifier then drives the LSS bus when its voltage is less than the speed or temperature control inputs. The fuel limit mode LED shows when the fuel limiter module is controlling fuel.

The fuel limiter module has a deceleration limiter circuit. The deceleration limiter controls the minimum fuel flow to the turbine. If fuel is decreased too rapidly, a flameout will occur. During start-up, the output of the LSS bus is high-signal selected. It has a fixed voltage when the engine speed is below 8400 rpm. This voltage limiter prevents the fuel valve from reaching the minimum fuel flow stop during start-up.

The acceleration temperature reference voltage increases as the turbine speed increases during acceleration. A CIT bias sets the reference lower as the ambient temperature decreases. An 8400-rpm speed switch and a start/run latch are used to select the temperature channel operating reference. Below 8400 rpm the latch is set to the start mode. This selects the acceleration temperature reference and start TIT LED. When the speed switch is above 8400 rpm and speed control has been achieved, the start/run latch is set to run. The run indicator LED lights up.

TEMPERATURE CHANNEL MODULE.— The temperature channel prevents turbine temperature from exceeding safe operating limits. A signal proportional to TIT is compared with the start or run temperature reference. The amplifier generates a voltage signal output to the LSS bus to limit TIT.

The temperature control amplifiers operate similar to the speed control amplifiers. Separate start and run LEDs are provided. They compensate for the longer thermocouple time constant at low turbine speeds. This lag is due to low airflow at low speeds.

A start fuel schedule supplies enough fuel for TIT to reach the acceleration temperature range (4000-5000 rpm). When the turbine reaches the acceleration range, the temperature control requires less fuel than the fuel limiter. The LSS bus then selects the temperature control for the rest of turbine acceleration.

When the turbine reaches isochronous or rated speed (60 Hz), the speed control takes control from TIT control. Then the start/run reference switches to run limit. TIT is a function of load on the turbine. If load is increased until TIT equals the TIT reference, the temperature control will maintain TIT at that level. In droop mode or when paralleled with other units, the generator load will be maintained at a level to produce the set TIT. When no other source is available to carry the excess load, the temperature control will reduce speed.

FINAL DRIVER MODULE.—The final driver module generates current to position the actuator as required by the controlling channel. An oscillator generates an excitation voltage for the LVDT located on the LFV. As mentioned before, the LVDT is mechanically linked to the fuel valve metering sleeve. It senses the fuel valve position. This sleeve is moved through the action of the actuator. As it moves, the excitation voltage transmitted to the LVDT output is changed. The output of the LVDT is proportional to the position of the fuel metering sleeve. A demodulator in the final driver changes the LVDT feedback signal to a d.c. voltage. This voltage is proportional to the sleeve position on the fuel valve. The final driver amplifier compares the input from the control circuits with the LVDT voltage. Then it correctly positions the fuel valve. The final driver and actuator are reverse acting. The less current supplied to the actuator, the greater the fuel supplied to the turbine.

MOTHERBOARD.—The motherboard's primary function is to interconnect the eight daughter boards with each other and the J1, J2, and J3 receptacles. The motherboard also has the power drive transistor for the actuator. This transistor is mounted on a heat sink which is connected to the chassis.

GTGS LOCAL OPERATING PANEL

The local operating panel (LOCOP) is the major operator interface with the GTGS. It has the controls and indicators necessary to start, stop, motor, and monitor GTGS operation. The LOCOP is also the interface with the ECSS which provides control of each GTGS at the EPCC. Many of the indicators available at the GTGS LOCOP are not available at the EPCC. This requires personnel to monitor the LOCOP during GTGS operation. Usually this monitor is a junior GS. For this reason, you should know and become very familiar with the material in this section.

Two LOCOPs are used to control the two different GTGS models. Their construction is radically different. They are made by two different manufacturers. Even though they are so different, they provide the engine and the operator almost identical signals and data. Their main difference lies in the method in which their data and signals are provided.

MODEL 104 LOCOP

The Model 104 LOCOP is contained in a cabinet mounted on the generator end of the module. On the outside of the cabinet doors are the controls and indicators for local GTGS operation. Inside the cabinet are the electronic components of the system. Among these components are printed circuit cards, voltage regulators, minus 24-volt d.c. converter module, a relay assembly, and a temperature and speed control unit. The control elements of the system are powered by 28 volts d.c. from the switchboard. The switchboard 28-volt d.c. supply has a bank of 15 amp-hr lead-acid batteries for backup. This battery bank allows starting of a GTGS when the ship is without 450-volt a.c. power.

Control Panel Layout

The following five sections detail the layout of the Model 104 LOCOP (figure 8-33). The letters after each item discussed correspond to the letters on figure 8-33.

MONITORING AND INDICATING INSTRUMENTS:

1. Generator air temperature meter (A)
2. Generator bearing temperature meter (with selector switch to select either bearing) (B)
3. Generator stator temperature meter (with selector switch to select any one of six temperature detectors) (C)
4. Enclosure temperature (turbine enclosure) (D)
5. HP start cycle counter (E) and LP start cycle counter (F)
6. Lube oil header pressure (reduction gear header) (G)
7. Engine rpm (H)
8. Running time (I)
9. Lube oil temperature (reduction gear header) (J)
10. Turbine inlet temperature (K)
11. Turbine vibration (L)

ALARM INDICATIONS WITH ENGINE SHUTDOWN:

1. FAIL TO FIRE—Failure to attain 600 °F TIT within 10 seconds after speed exceeds 2200 rpm (M)

2. START OVERTEMP—TIT greater than 1600 °F at speeds below 12,780 (N)

3. ENGINE OVERTEMP—TIT greater than 1945 °F at speeds above 12,780 rpm (O)

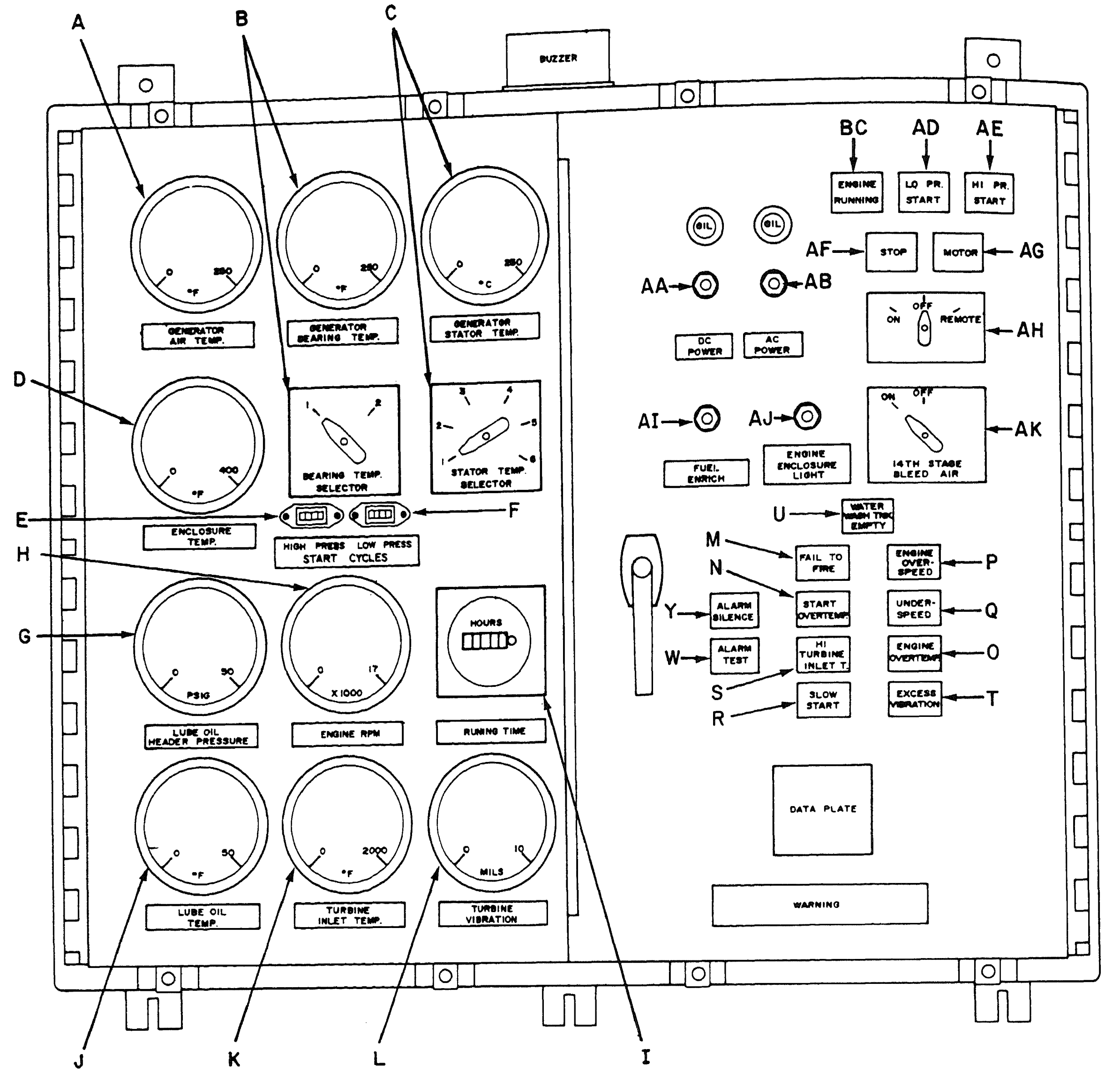

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Figure 8-33.—Model 104 LOCOP.

4. ENGINE OVERSPEED—Speed greater than 15,800 rpm (P)

5. UNDERSPEED—Speed below 12,780 rpm after having been above 12,780 rpm for 2 seconds (Q)

When engine shutdown occurs because of these abnormal conditions, the control system will prevent restarting. It prevents restarting until the alarm condition no longer exists and the 2-minute coastdown timer has expired.

ALARM INDICATIONS ONLY:

1. SLOW START—Failure of engine to reach 12,780 rpm within 2 minutes after start initiation (R)

2. HI TURBINE INLET—TIT greater than 1880 °F at speeds above 12,780 rpm (S)

3. EXCESS VIBRATION—Turbine vibrations in excess of 3 mils peak-to-peak at a frequency above 140 Hz (T)

OTHER ALARM DISPLAYS AND FUNCTIONS:

1. Turbine WATER WASH TANK EMPTY (U).

2. ALARM SILENCE Pushbutton. When an alarm condition occurs, corresponding indicators flash red and a buzzer is energized. The alarm silence pushbutton also lights up red. When depressed, the buzzer is silenced and the indicated alarm light becomes steady red. When the abnormal condition no longer exists, the alarm indicator will turn off automatically (V).

3. ALARM TEST Pushbutton. When depressed, it will cause all alarm indicators to flash and the buzzer to sound. The alarms are then reset with the alarm silence pushbutton. This test assures you that the alarm indicators and alarm logic circuits are fully operative (W).

When the engine is operating with TIT greater than 1600 °F and a shutdown occurs because of underspeed, the UNDERSPEED indicator will flash and the START OVERTEMP indicator will light up steady. This condition remains true until the alarm silence pushbutton is depressed, and the abnormal conditions no longer exist. This function shows you the abnormal condition that actually caused the shutdown.

CONTROL INDICATORS AND PUSHBUTTONS:

1. DC POWER (on-off toggle switch)—Provides all power necessary to start and run the gas turbine (AA).

2. AC POWER (on-off toggle switch)—Provides 115 volts, 60 Hz for enclosure lights and running time meter (AB).

3. ENGINE RUNNING Indicator—Illuminates at speeds above 12,780 rpm (AC).

4. LO PRESS START (low-pressure start pushbutton/indicator—Provides for engine starting on the bleed air system (normal) (AD).

5. HI PRESS START (high-pressure start pushbutton/indicator)—Provides for engine starting on the HP system (emergency) (AE).

6. STOP—Provides for stopping the engine regardless of the ON-OFF-REMOTE selector switch position (AF).

7. MOTOR—Provides for motoring the engine regardless of the ON-OFF-REMOTE selector switch position (AG).

8. ON-OFF-REMOTE Selector (AH).

ON—Enables LP and HP start pushbuttons on enclosure door.

OFF—Prevents starting of engine from any location.

REMOTE—Transfers only start control functions to the associated switchboard and/or the EPCC (local indicators, alarms, stop, and motor function remain operative).

9. FUEL ENRICH (on-off toggle switch)—Provides for cold weather starting of engine (AI).

10. ENGINE ENCLOSURE LIGHT (on-off toggle switch) (AJ).

11. 14TH-STAGE BLEED AIR (on-off selector switch)—ON position enables the control system that opens, regulates, and closes the 14th-stage bleed air valve (AK).

Model 104 LOCOP Electronics

The equipment mounted inside the LOCOP has fuses, power supplies, relays, a 28-volt d.c. powerline filter, logic cards, signal conditioning cards, alarm cards, solenoid driver cards, contact buffer cards, a vibration card, and the

temperature and speed control box. Figure 8-34 shows the internal layout of the LOCOP.

Both 115 volts a.c. and 28 volts d.c. are required for normal operation of the LOCOP. However, the GTGS may be started with only the 28-volt d.c. supply. The GTGS enclosure lights are energized through cabinet door interlock relay contacts and the ENGINE ENCLOSURE LIGHT switch. The running time meter is energized through cabinet door interlock relay contacts, the AC POWER switch, and relay contacts. The contacts close when the GT is running. All the 115-volt a.c. circuits are protected by the F1 and F2 (15 amp) fuses. The +28 volts d.c. electronic circuits are supplied through a powerline filter, F3 (20 amp) fuse, and the DC POWER switch. The ignition exciter is supplied through the F4 (10 amp) fuse and contacts of a relay operated from the logic circuits.

Conversion of the 28-volt d.c. power to the voltage levels needed by the logic is done by a +15 and −15 volts regulator, a −24 volts converter, and a +5 volts regulator.

The −24 volts converter uses a transistorized and zener diode controlled oscillator. It is fed by the +28 volts d.c. supply. The oscillator output is a transformer coupled to a full-wave bridge rectifier. After filtering, the unregulated −24 volts d.c. is used as an input to the −15 volts d.c. regulator (adjustable). This regulator is on the same printed circuit board as the +15 volts d.c. regulator. It is fed from the +28 volts d.c. source.

The circuit cards are of several different types.

1. Relay (or solenoid) drivers energize relays or solenoids in response to a signal from a logic unit. They are used because the relay and solenoid coils require more current than can be supplied directly from a logic unit.
2. Contact buffers minimize the effect of contact bounce (due to operation of pushbutton or relay contacts) on a logic input.
3. RTD signal conditioners convert generator stator, air, lube oil, and bearing temperatures to signals used for local and remote monitoring.
4. The RTD/pressure signal conditioner converts engine enclosure temperature and lube oil header pressure to signals for local and remote monitoring.
5. A set point 1850 to 1870°F card converts TIT signal from the speed temperature control unit for control of the 14th-stage bleed air valve.
6. The vibration signal conditioner is a special card. It is used to convert the signal from a vibration pickup unit to a signal for local and remote monitoring and alarm.
7. Logic cards sequence the various events during a turbine start and/or stop.
8. Alarm cards initiate turbine shutdown and local alarms for abnormal turbine operating conditions.
9. The alarm control card controls alarm light flashing and buzzer energizing.

Turbine Temperature and Speed Control Box

The turbine temperature and speed control is a combination electronic speed switch and temperature amplifier. It is mounted in the LOCOP. The control receives a speed signal from a magnetic pickup on the PTO shaft and a temperature signal from the turbine inlet thermocouples. These signals position control relays in four speed channels and five temperature channels within the box. They also provide signals for local and remote monitoring of speed and TIT. In combination with logic circuitry described in the last section, the four speed channels and five temperature channels provide the functions as described below.

2200 RPM SPEED CHANNEL:

1. Energizes the ignition circuit.
2. Energizes the fuel shutdown valve solenoid (open).
3. Energizes the fuel pump paralleling valve solenoid (closed) to place the fuel pump HP primary and secondary elements in parallel operation.
4. Energizes the fuel enrichment valve solenoid. The valve will open if fuel enrichment has been selected. When manifold pressure reaches 50 psig, the fuel enrichment valve solenoid will de-energize, closing the valve.
5. De-energizes the start temperature limit valve solenoid, closing the drain port and opening the pressure port to the LFV acceleration control section.

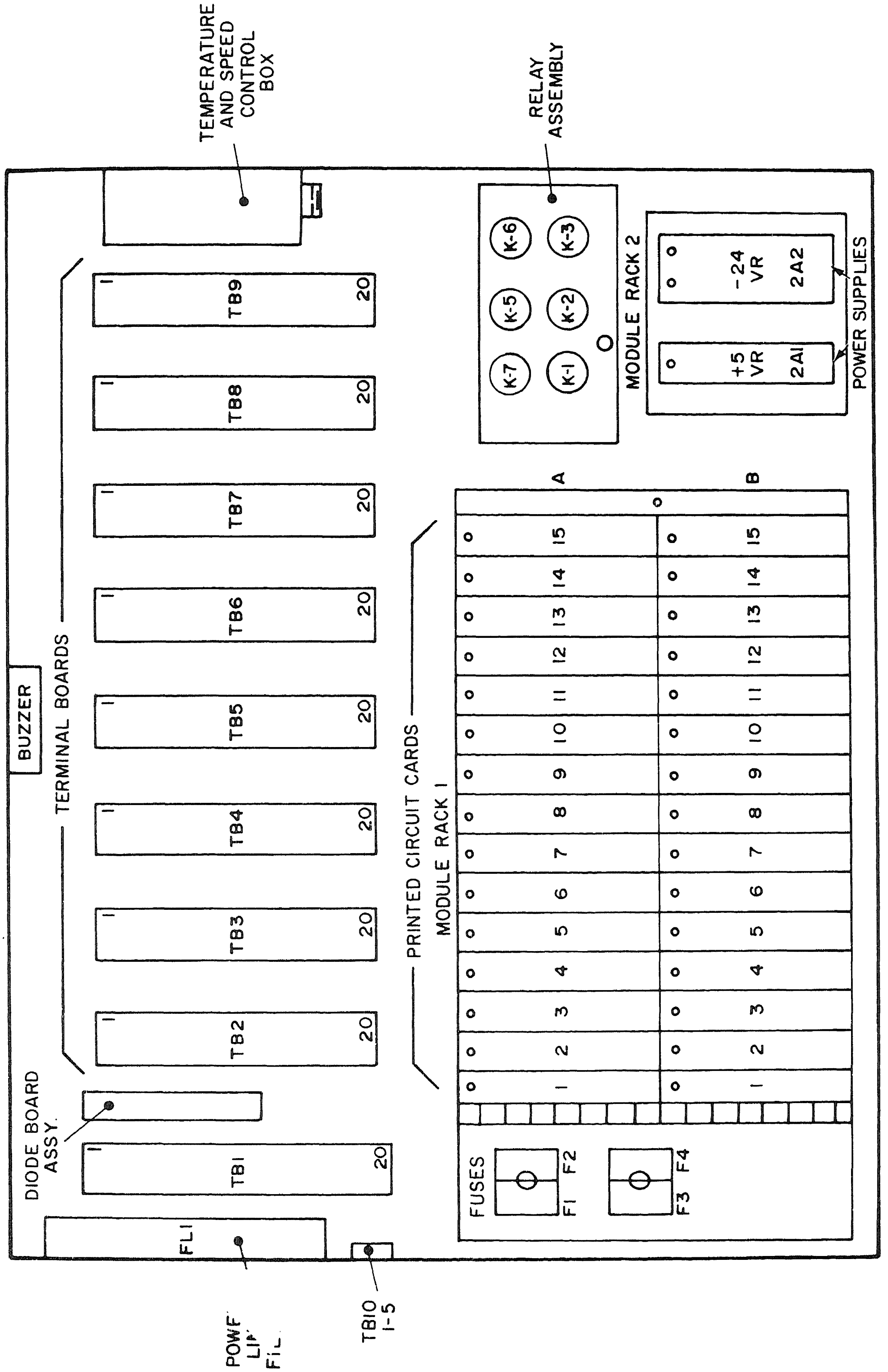

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Figure 8-34.—LOCOP internal layout.

6. Arms the start temperature limit valve control to cycle the start temperature limit valve solenoid (on and off) to reduce TIT if it exceeds 1500 °F.

7. Starts the 10-second fail-to-fire timer. If TIT fails to reach 600 °F through the 600 °F temperature channel before the timer elapses, the fail-to-fire circuit will initiate an automatic shutdown.

8. Energizes the running time meter relay to start the meter.

8400 RPM SPEED CHANNEL:

1. Inhibits the fuel paralleling valve, enrichment valve, and ignition circuits to prevent reactivation during a shutdown.

2. De-energizes the ignition circuit.

3. De-energizes the fuel pump paralleling valve solenoid (open) to place the HP fuel pump primary and secondary elements in series operation.

4. De-energizes the LP (or HP) start air valve solenoid (closed) to cut out the starter.

5. Extinguishes the LP (or HP) start push-button indicator.

6. De-energizes the GTM HP start inhibit relay if the GTGS was started on HP air. Allows GTM in same engine room to be started on HP air.

12,780 RPM SPEED CHANNEL:

1. Inhibits the start temperature limit valve control circuit to permit TIT to increase above 1500 °F.

2. Inhibits the start overtemperature shutdown circuit to permit TIT to increase above 1600 °F.

3. Arms the engine overtemperature shutdown circuit to shutdown the turbine if TIT increases to 1945 °F.

4. Inhibits the slow start alarm circuit.

5. Starts the 2-second underspeed timer. When elapsed, it will arm the underspeed shutdown circuit to automatically shut down the turbine. This happens if speed decreases below 12,780 rpm during operation.

6. Lights up the ENGINE RUNNING indicator light.

7. Enables the 14th-stage bleed valve control circuit to permit opening of the valve (when selected) as long as TIT is not greater than 1850 °F. Once opened below 1850 °F, the valve will remain open until TIT reaches 1870 °F. At this point the valve will start closing to try to hold TIT below 1870 °F. When TIT drops below 1870 °F, the valve position will stabilize at an interim position. The valve will not close further until TIT again reaches 1870 °F. It will not completely open again until TIT drops below 1850 °F. If TIT remains above 1870 °F, the valve will fully close. It will remain closed until TIT decreases below 1850 °F.

15,800 RPM SPEED CHANNEL: Provides engine overspeed protection. If engine speed exceeds 15,800 rpm, an automatic shutdown is initiated.

600 °F TEMPERATURE CHANNEL: Provides automatic shutdown if 600 °F TIT is not reached within 10 seconds after reaching 2200 rpm.

1500 °F TEMPERATURE CHANNEL: Activates the start temperature limit valve control circuit. The circuit intermittently energizes the start temperature limit control valve solenoid through a pulse timer. This reduces acceleration fuel flow, and thereby reduces TIT below 1500 °F.

1600 °F TEMPERATURE CHANNEL: Starts an automatic shutdown if 1600 °F TIT is reached below 12,780 rpm.

1880 °F TEMPERATURE CHANNEL: Causes an alarm to sound if 1880 °F TIT is reached.

1945 °F TEMPERATURE CHANNEL: Starts an automatic shutdown if 1945 °F TIT is reached above 12,780 rpm.

MODEL 139 GTGS LOCOP

The Model 139 LOCOP provides start/stop sequencing for the GTGS, monitoring and alarms for critical turbine and generator parameters, and signal conditioning for panel meters and transmission of selected data to the ECSS.

The LOCOP is contained in a cabinet mounted on the generator end of the module. On the outside of the cabinet doors are the controls and indicators for local GTGS operation. Inside the cabinet are the electronic components of the system. Among these components are printed circuit cards, voltage regulators, a ±12 volts d.c. converter module, a relay assembly, and a temperature and speed control unit. The control elements of the system are powered by 28 volts d.c. from the switchboard. The switchboard 28-volt d.c. supply has a bank of 15 amp-hr lead-calcium batteries for backup. This battery bank allows starting of a GTGS when the ship is without 450-volt a.c. power.

Control Panel Layout

The following section details the layout of the Model 139 LOCOP (figure 8-35, a foldout at the end of this chapter). The letter or letter/number combination with each item corresponds to the location of the item on figure 8-35.

Model 139 LOCOP Electronics

The Model 139 LOCOP is a computer controlled digital system. It uses a central microprocessor to control and monitor the GTGS. Figure 8-36 shows the internal layout of the parts of the Model 139 LOCOP. The LOCOP has the necessary power supplies to power all logic and switching level voltages.

The LOCOP system power supply printed circuit card and associated heat sink are mounted on the left side of the LOCOP cabinet. The system has the following components.

1. A d.c.-d.c. converter that supplies ±5 volts d.c. and ±15 volts d.c.

2. A switching power supply that supplies ±12 volts d.c. and ±10 volts d.c.

3. A switching power supply that supplies ±5 volts d.c.

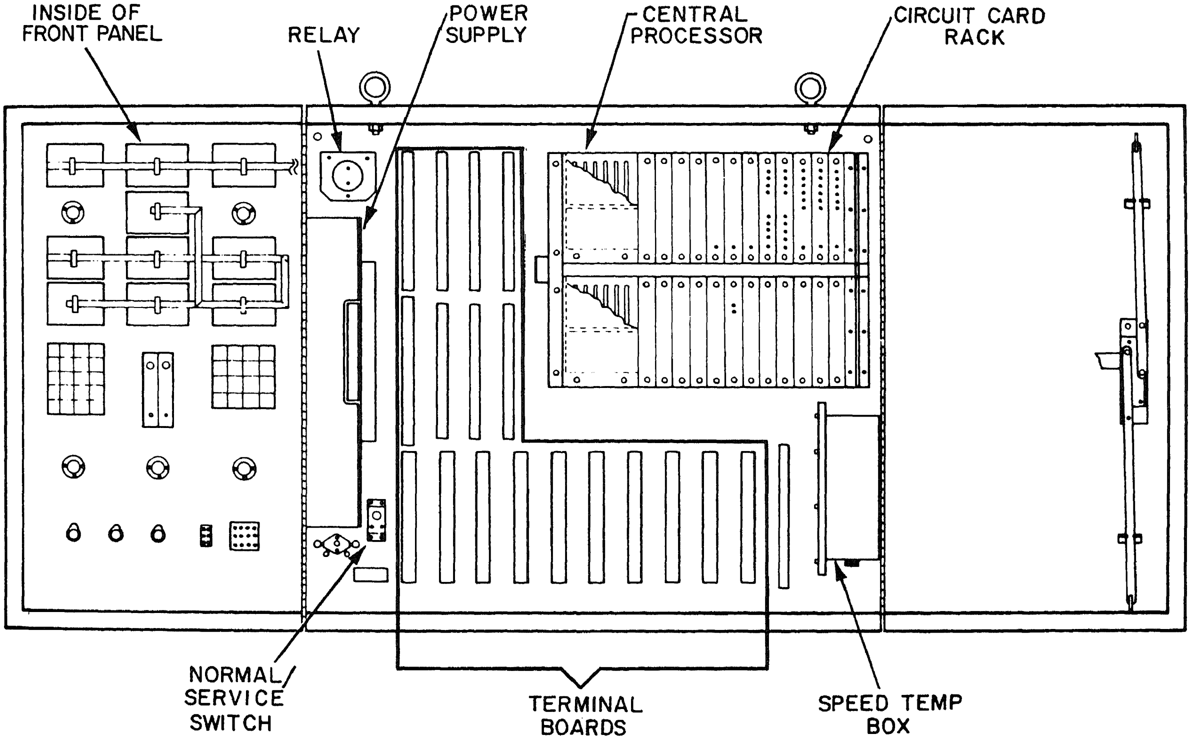

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Figure 8-36.—Model 139 LOCOP internal layout.

The audible alarm system has a printed circuit card where six different audible signals are electronically generated. Any one of the six are programmably selected. The selected signal is then amplified by the alarm amplifier assembly. The amount of amplification is adjustable to fit the environment. The printed circuit card is mounted in the card rack. The alarm amplifier assembly and speaker are mounted on the right side of the LOCOP cabinet.

For general description purposes, we have grouped the LOCOP electronics into their associated tasks.

CPU, MEMORY, I/O INTERFACE.—These three cards make up the system computer control. The CPU card has the microprocessor. The memory card has the system control program and data storage memory space. The I/O interface card provides the link between the computer control and the outside world. The LOCOP has two computer control systems for faster, more efficient control of the GTGS and for backup purposes.

BUS CONTROLLER.—This card generates the system's real time clocks and the synchronization signals. These are required to allow the two computer control units to operate together.

I/O MEMORY.—This card has data storage memory space. It is independent of the computer control memory. This memory may be used by either computer control system where data needs to be shared between them.

CONTACT BUFFER.—This card has 16 inputs to interpret a switch closure. Electronics are included to interrupt the microprocessor so the special task requested by the switch can be handled. The card may be programmed to accept normally open or closed contacts. It will interrupt the microprocessor on both transmissions of the switch. There are two cards per LOCOP system.

SWITCH BUFFER.—This card has eight inputs to interpret a switch closure. It differs from the contact buffer by interrupting the microprocessors only upon initial closure. The switch release is not buffered. There are two cards per LOCOP system.

LAMP DRIVER.—This card has eight output driver circuits used to illuminate the visual indicators on the LOCOP front panel. The indicators can burn steadily or flash depending on the control program. There is also circuitry. If a lamp fails, the microprocessor will be interrupted to indicate an internal failure. There are three cards per LOCOP system.

RELAY CONTROL.—This card has eight relays, all independently controlled by the control program. Each relay provides normally open and normally closed contacts. There is also circuitry to detect a failure of the driver circuits. The circuits will interrupt the microprocessor to indicate an internal failure. There are two cards per LOCOP system.

SOLENOID DRIVER.—This card contains six solenoid driver circuits. All are independently controlled by the control program. There is circuitry to detect a failure of the driver circuits or a shorted solenoid. This will interrupt the microprocessor to indicate an internal failure.

DISPLAY CONTROL/DIGITAL METER.—This card receives, from the computer control, the digitized monitor data. It then directs this data to the associated digital display card located on the LOCOP front door. Up to 16 channels may be handled.

ANALOG TO DIGITAL CONVERTER (ADC), DIGITAL TO ANALOG CONVERTER (DAC).—These three cards make up the monitor data handling system of the LOCOP. The analog input/multiboard has eight input circuits with 10-mA output current sources. These inputs are designed to accept 0 to 10 volts d.c. The data can be attenuated or amplified by electronics or the control program. Once conditioned, this card multiplexes the data to be digitized by the ADC card. The digitized data is then sent to the I/O memory card for storage. The control program then conditions this data for the digital displays and analog output card. The analog output card can convert up to eight channels of data to a 0- to 10-volt d.c. signal. This analog signal can be used depending on the control program. There are two analog input cards, two analog output cards, and one ADC card per LOCOP.

VIBRATION MONITOR.—This card monitors the engine vibration pickup and scales it for control purposes. The card also splits the signal and sends it to the remote monitor outputs and analog input card. Also an electronic switch circuit detects high vibration. It signals the microprocessor control via a contact buffer input.

ALARM BOARD.—This card generates the alarm tones required for the audible alarm system. Six tones are possible. There is also circuitry to adjust the volume of the audible alarm.

I/E CONVERTER.—This card converts the 4- to 20-mA pressure transducer current outputs to 0 to 10 volts d.c. Buffer circuits enable multiple outputs of these signals as well as RPM and TIT signals. There is also circuitry to calibrate the RPM/TIT analog meter on the LOCOP front panel. An electronic switch closure is adjustable for any predetermined RPM set point.

ALLISON SPEED/TEMP CONTROL BOX.—This unit, supplied by Allison, generates switch closures required by the computer control system to control the GTGS. These include engine speed as well as engine TIT set points. The unit also supplies the signals for the analog RPM/TIT meter located on the LOCOP front door.

The speed and temperature channels on the Model 139 are almost identical to the channels used on the Model 104 set. There are a few exceptions as follows.

- Fuel enrichment is not used so it is not enabled at 2200 rpm.

- The start temperature limit control valve is not used on the Model 139. No signal is sent to it at 2200 rpm or 12,780 rpm.

- During start above 2200 rpm, the engine must accelerate at a rate of 40 rpm/second over any 3-second period. When this is enabled by the 2200-rpm speed channel, and the engine fails to accelerate at that rate, an antistagnation feature will shut down the engine and sound the slow start alarm.

- The 1945 °F temperature channel has been reset to 2050 °F. This is to allow for higher load transients. The 1880 °F temperature channel remains the same.

GTGS STARTING AND STOPPING

Both Model GTGSs have a fairly common start/stop sequence. The major difference is found in fuel control during starting. The Model 104 GTGS accelerates using the start temp limit control valve and LFV to control the fuel schedule. The Model 139 accelerates using the governor for fuel scheduling to engine run. Because of this difference, we will describe the sequence for the Model 104 and discuss where differences lie in the Model 139.

AUTOMATIC START/STOP

The GTGS control system provides the automatic start sequencing logic, monitoring of critical parameters, and alarm shutdown functions. A logic flow diagram of the start sequence is shown in figure 8-37. Following is a description of the events that occur.

Start Initiation

Momentarily press the LOW (or HIGH) PRESSURE START pushbutton switch. The engine may be started from either the LP or HP air system. The respective air systems must have been previously aligned. The normal start system is LP air (bleed air). Emergency start system is HP air.

1. The stop pushbutton switch will extinguish. The LOW (or HIGH) PRESSURE START pushbutton will illuminate.
2. The LP (or HP) air solenoid will energize. During an HP start of No. 1 or No. 2 GTGS, the GTM HP start inhibit relay will energize. This inhibits the HP start of a GTM within the same engine room.
3. The LP (or HP) air start cycle counter will advance one number.
4. The start temperature limit valve solenoid is energized. The pressure port closes and the drain opens. This allows the GTGS to start

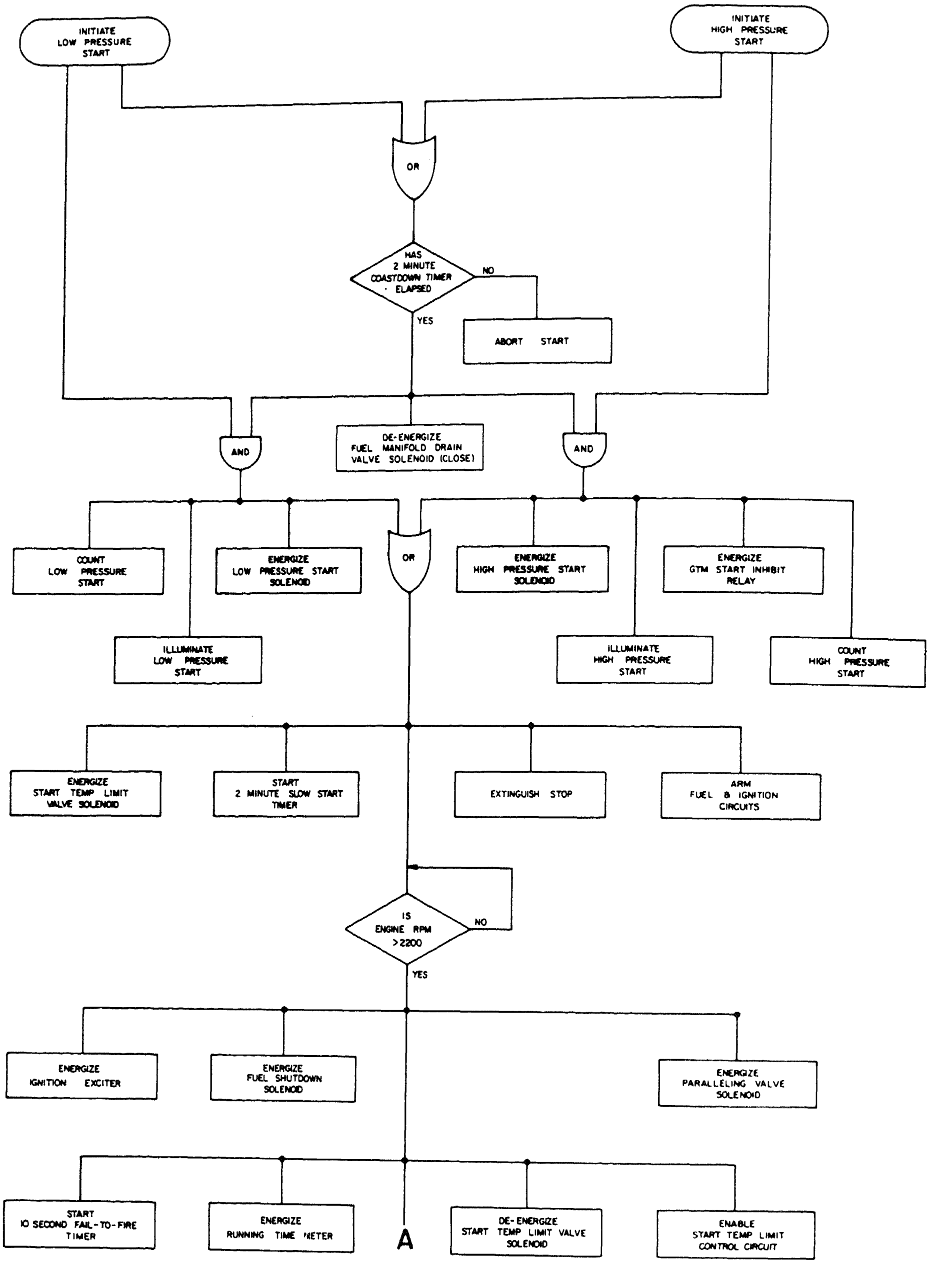

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Figure 8-37.—GTG start sequence flow diagram.

on the minimum fuel setting. (Not on the Model 139.)

5. The fuel and ignition circuits are armed.

6. The 2-minute slow start timer is energized.

Acceleration Under Starter Power

The engine accelerates under starter power. At 2200 rpm the following conditions occur.

1. The ignition system is energized.

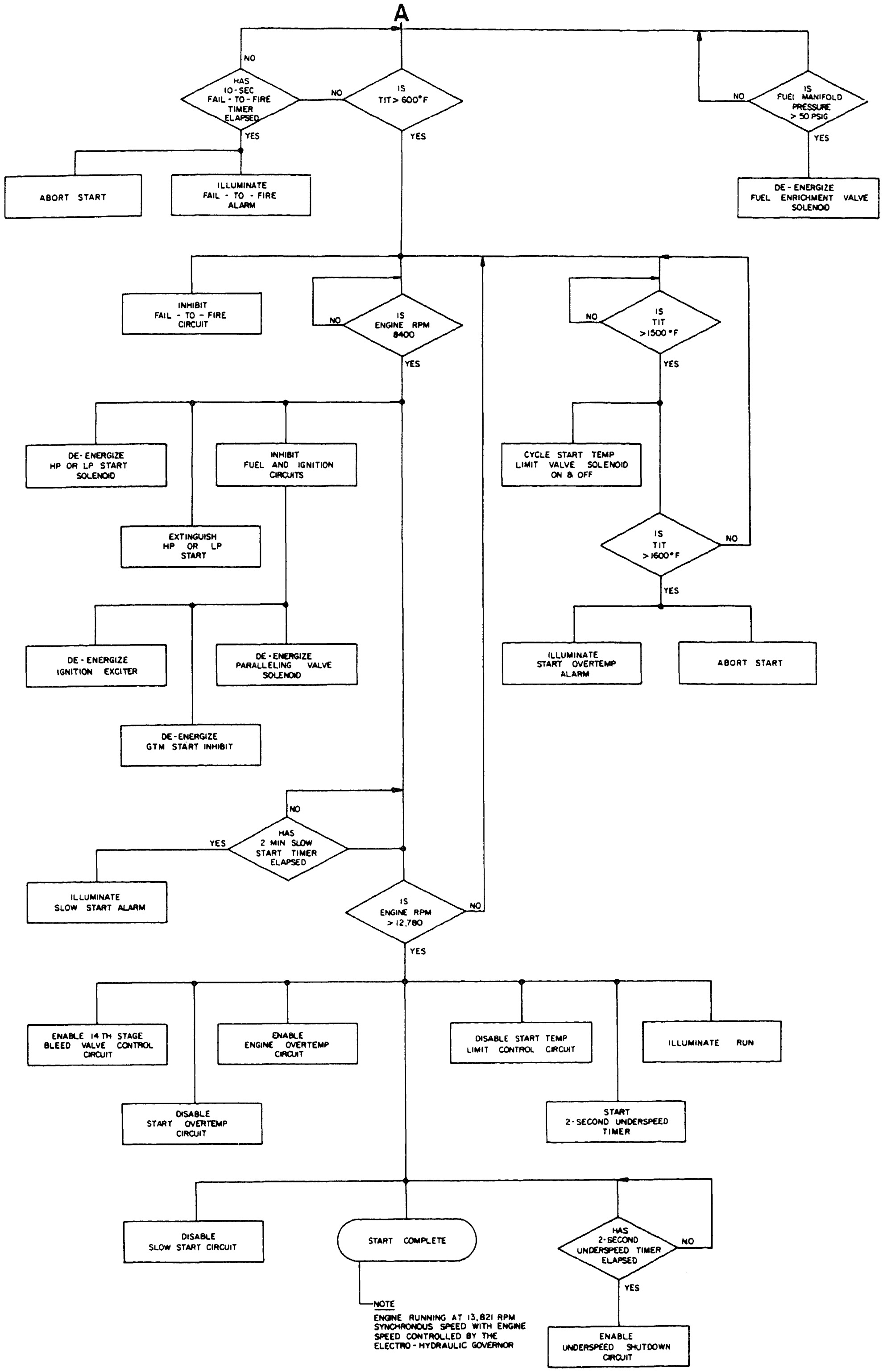

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Figure 8-37.—GTG start sequence flow diagram—Continued.

2. The fuel shutdown valve solenoid is energized (opened).

3. The fuel pump paralleling valve solenoid is energized (closed). This places the fuel pump HP primary and secondary elements in parallel operation.

4. The fuel enrichment valve solenoid is energized (opened) if fuel enrichment has been selected. When fuel manifold pressure reaches 50 psig, the fuel enrichment valve solenoid will de-energize. This closes the valve. (Not used on the Model 139).

5. The start temperature limit valve solenoid will de-energize. The drain port closes and the pressure port opens to the acceleration control section. The turbine will be accelerated at a rate equal to CDP increase modified by CIT. (Not used on the Model 139.)

6. The start temperature limit valve control circuit is armed. If TIT reaches 1500 °F, the start temperature limit valve control circuit will intermittently energize the start temperature limit valve solenoid. It does this through a pulse time. This reduces acceleration fuel flow, and thereby reduces TIT below 1500 °F. (Not used on the Model 139.)

7. The 10-second fail-to-fire timer is started. If TIT fails to reach 600 °F through the 600 °F temperature channel before the timer elapses, the fail-to-fire circuit will start an automatic shutdown. If 600 °F TIT is reached before the timer elapses, the fail-to-fire shutdown circuit is inhibited.

8. The running time meter is energized.

9. On the Model 139, the antistagnation circuit is enabled.

Acceleration Under Starter and Engine Power

The engine accelerates under starter and engine power. At 8400 rpm the following occurs.

1. The fuel paralleling valve, enrichment valve, and ignition circuits are inhibited. This prevents reactivation during a shutdown.

2. The ignition circuit is de-energized.

3. The fuel pump paralleling valve solenoid is de-energized (open). This places the HP fuel pump primary and secondary elements in series operation.

4. The LP (or HP) start air valve solenoid is de-energized (closed) to cut out the starter.

5. The LOW (or HIGH) PRESSURE START pushbutton/indicator will extinguish.

6. The GTM HP start inhibit relay will de-energize if GTGS was started on HP air. This allows the GTM in the same engine room to be started on HP air.

Acceleration Under Engine Power

The engine accelerates under turbine power. At 12,780 rpm the following occurs.

1. The start temperature limit valve control circuit is inhibited. This permits TIT to increase above 1500 °F during normal operation. (Not used on the Model 139.)

2. The start overtemperature shutdown circuit is inhibited. This permits TIT to increase above 1600 °F during operation.

3. The engine overtemperature shutdown circuit is armed. If TIT increases to 1945 °F (2050 °F in the Model 139), the circuit will initiate an automatic shutdown.

4. The slow start alarm circuit is inhibited.

5. The 2-second underspeed timer is started. When elapsed, the underspeed shutdown circuit is armed. If turbine speed decreases below 12,780 rpm after the 2-second time has elapsed, an automatic shutdown will be initiated.

6. The ENGINE RUNNING indicator light will illuminate.

7. The 14th-stage bleed valve control circuit is enabled. This permits opening of the valve (when selected) as long as TIT is not greater than 1850 °F. Once opened below 1850 °F, the valve will remain open until TIT reaches 1870 °F. At this point, the valve will start closing to try to hold TIT below 1870 °F. When TIT drops below 1870 °F, the valve position will stabilize at an interim position. The valve will not close further until TIT again reaches 1870 °F. It will not completely open again until TIT drops below 1850 °F. If TIT remains above 1870 °F, the valve will fully close. It will remain closed until TIT decreases below 1850 °F.

ALARM/SHUTDOWN FUNCTIONS

During operation, the GTGS control system provides the logic for the following alarm/shutdown functions.

1. Alarm only functions
   - SLOW START (shutdown on Model 139 for antistagnation)
   - HIGH TURBINE INLET TEMPERATURE
   - EXCESSIVE VIBRATION
2. Automatic shutdown and alarm functions
   - FAIL TO FIRE
   - START OVERTEMPERATURE
   - ENGINE OVERTEMPERATURE
   - ENGINE OVERSPEED
   - UNDERSPEED
3. Additional functions
   - Prohibits opening of the 14th-stage bleed air valve at speeds below 12,780 rpm.
   - Inhibits starting for 2 minutes after a shutdown to allow the unit to coast down. (Three minutes on the Model 139.)
   - Regulates 14th-stage bleed air valve to maintain TIT at less than 1870°F.
   - Provides analog information to the ECSS for alarm and data systems.

INSTRUMENTATION AND MONITORING INTERFACE WITH THE ECSS

Information sent to the ECSS may be conditioned in the LOCOP or it may be sent to the ECSS for processing. The following material describes the data that is used by the ECSS and how it is processed.

INFORMATION CONDITIONED BY THE LOCOP

The following signals are conditioned to a 0- to 10-volt d.c. level by the signal conditioner cards. They are then distributed to the ECSS.

1. Lube oil header pressure
2. Generator stator temperatures (No. 1 through No. 6)
3. Generator bearing temperatures (No. 1 and No. 2)
4. Lube oil temperature
5. Generator air temperature
6. Engine enclosure temperature
7. TIT
8. Engine rpm
9. Vibration
10. GTGS No. 3 start air temperature

INFORMATION DIRECT TO THE ECSS

The following signals from either pressure or temperature switches are sent directly from within the GTGS to the ECSS.

1. Generator/reduction gear lube oil pressure low alarm
2. Enclosure temperature high alarm
3. Generator air temperature high alarm
4. Generator bearing temperature high alarm (front and rear)
5. Generator stator temperature high alarm
6. Module fire
7. Reduction gear lube oil temperature high alarm
8. Fuel oil strainer ΔP high
9. Lube oil strainer ΔP high

GTGS SUPPORT SYSTEMS

The GTGS has several support systems that provide cooling water or air to permit engine operation. The GTGS must be able to operate without relying on the other ship's systems. (One exception to this is the fuel oil service system. However, head tanks are installed that allow several hours of generator operation without operating the fuel oil service system.)

SEAWATER SERVICE SYSTEM

Each GTGS has an independent seawater service system. These are for the lube oil coolers and

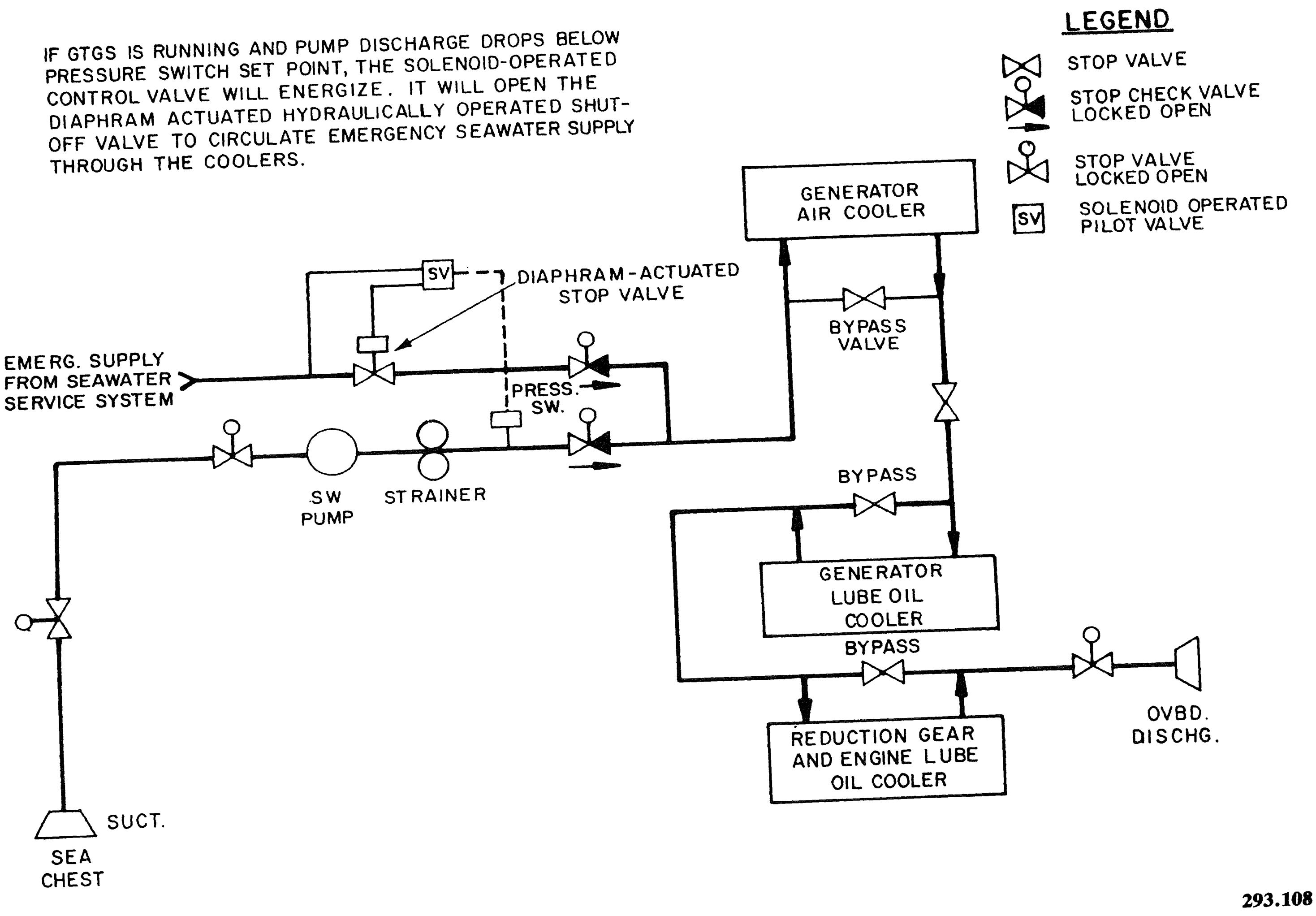

Figure 8-38.—Generator seawater service system.

generator air cooler. An electric pump starts automatically as the generator voltage builds up. This is done because power is taken from the generator side of the main circuit breaker. If the electric pump system fails, emergency cooling water is supplied by the ship's seawater service system. Figure 8-38 is a flow diagram of this service system. A solenoid-operated pilot valve opens. It automatically opens the diaphragm activated, hydraulically operated stop valve when LP contacts close in the pressure switch in the normal service line. Cooling water is drawn from the sea chest. It flows through the generator air cooler and lube oil cooler. It then passes through the engine lube oil cooler. The seawater flow requirements are different for the three coolers. Therefore, each unit has a bypass valve to adjust seawater flowing through the cooler.

INTAKE AND EXHAUST SYSTEMS

The intake and exhaust systems (figure 8-39) provide the flow path for combustion and cooling

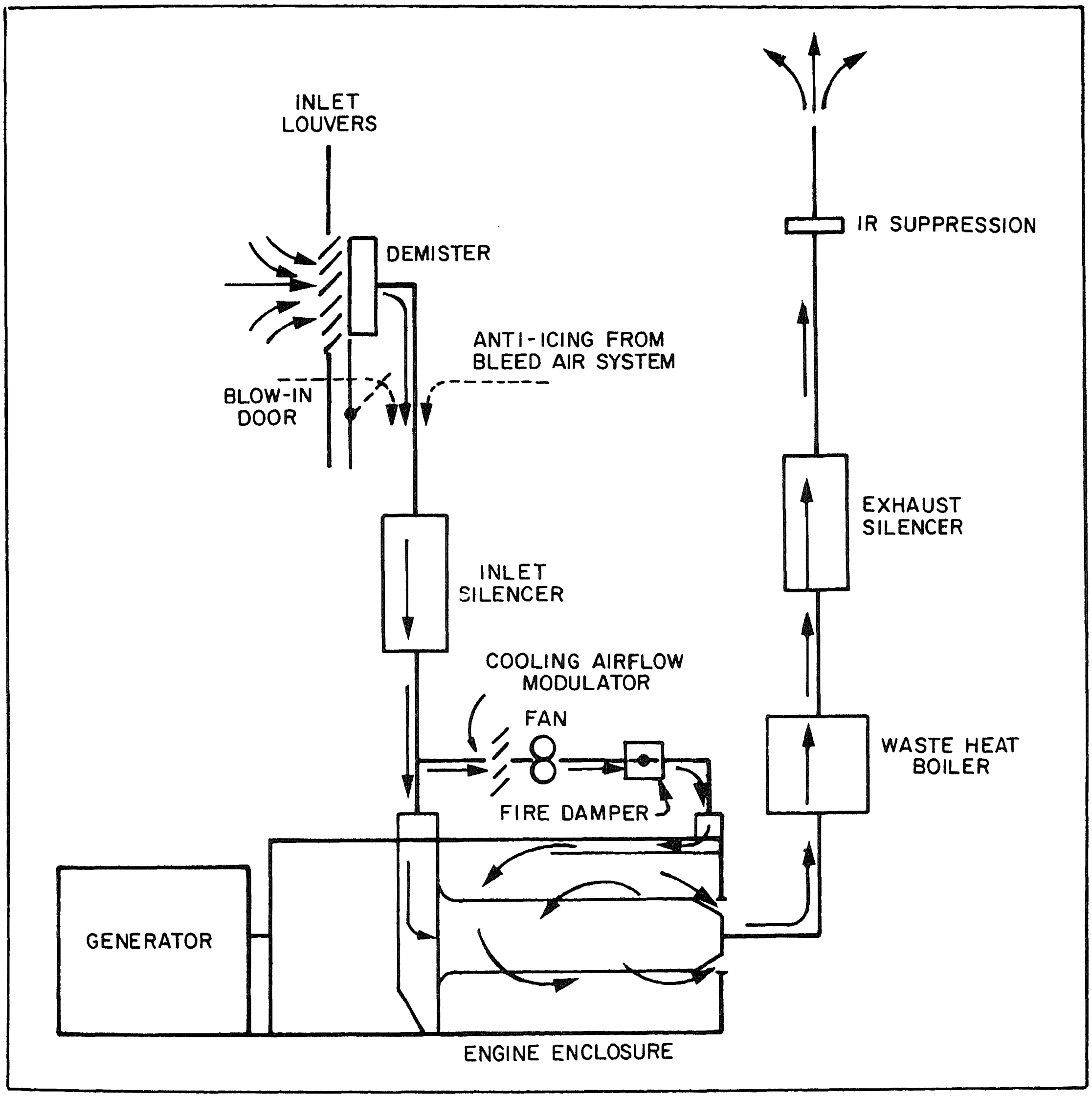

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Figure 8-39.—GTGS intake, cooling, and exhaust system.

air to the GT. They also provide for engine exhaust gas discharge. The inlet systems have inlet louvers, demisters, blow-in doors, silencers, cooling airflow modulators, fans, and fire dampers. The exhaust systems contain silencers and IR suppression systems. The exhaust gas from all three engines is routed through waste heat boilers before entering the exhaust stack.

Intake Duct

The intake ducts are rectangular structures. The ducts for the No. 1 and No. 2 engines are located in the inboard side of the exhaust stacks. Air enters the ducts through louvers mounted in the side of the stack. It flows through mesh pad type of demisters, through silencers, into the module inlet plenum, and into the engine inlet. The intake air inlet for GTGS No. 3 is located on the 01 level, starboard side, aft of the missile launcher area. Air enters a vertical bellmouth and flows downward into generator No. 3 inlet plenum. This plenum serves as a green water trap. It allows any large quantities of water to drain through slots in the deck combing. The air then flows through demisters into generator No. 3 intake room. The bulkhead between these two compartments has the blow-in doors. Combustion and cooling air flow through separate ducts from the intake room to the module.

Louvers

The intake duct inlets for the No. 1 and No. 2 engines have louvers similar to the main engine inlet louvers. Like the main engine louvers, they are designed and arranged to shed sea spray. Because of the vertical flow inlet design, the No. 3 engine duct inlet has no louvers.

Demisters

The demisters are mesh pad type. They are similar to those in the main engine inlet. They are arranged vertically behind the louvers. Moisture separated from the air collects in scuppers under the demisters and is drained overboard.

Blow-In Doors

A single blow-in door is located in each inlet below the demisters. Their purpose is to bypass the demisters if they become clogged. This permits enough combustion and cooling airflow to the engine for normal operation. A controller provides for manual or automatic operation by a selector switch on the controller door. When in manual, a pushbutton will energize a solenoid and release the blow-in door. When in automatic, the solenoid is energized by action of a pressure switch. This switch is set to operate at about 8 inches of water (in. H_2O) differential pressure. Indication and alarm of DUCT PRESS LO are given at PLOE and PAMCE. Once open, the doors must be closed manually.

Silencers

The vane-type silencers have sound deadening material encased in a perforated, stainless steel sheet. They are mounted vertically in the duct between the demisters and the cooling air duct.

Module Cooling

The module cooling system has a duct, an airflow modulator, an axial fan (two fans on the Model 139), a fire damper, an air silencer, and a ceiling-mounted baffle within the module.

FLOW MODULATOR.—The flow modulator is located in the cooling duct between the engine intake duct and the fan. It controls the flow of air to the module enclosure with respect to enclosure temperature. When the enclosure temperature increases to 180°F, the high temperature set point contacts of the module-mounted thermostat will close. This causes the flow modulator motor to rotate the modulating blade-type vanes to the full open position. When the enclosure temperature decreases to 170°F, the low temperature set point contacts will close. This causes the flow modulator motor to rotate the modulating vanes back to the half-open position. The modulator is not used on the Model 139 GTGS.

FAN.—The fan is located in the cooling air duct between the flow modulator and the fire damper. The fan draws air from the intake duct through the flow modulator. It blows the air through the fire damper to the module enclosure. Two fans are used on the Model 139. The air enters the module through the silencer. It passes down across the ceiling-mounted baffle within the enclosure. The air then circulates around the engine. It exits through a gap between the engine exhaust nozzle and the exhaust eductor section. There it mixes with the engine exhaust.

COOLING FAN CONTROLLER.—The fan controller is provided with a NORMAL/ALTERNATE power supply selector switch. It has a circuit to cycle the fan on and off automatically with respect to enclosure temperature. There is also circuitry to perform a GTGS system fire stop which is described later in this chapter. The NORMAL source for the controller is the generator bus; the ALTERNATE source is one of the other two switchboards. The fan will cycle on when a temperature switch within the module enclosure senses a temperature of 175 °F. It cycles off when the temperature decreases to 160 °F. The Model 139 cycles on and off with respect to temperature also, but this is controlled by the LOCOP.

FIRE DAMPER.—The fire damper is located in the cooling air duct between the fan and module enclosure. It closes off the flow of cooling air to the module when a fire is present within the module. During normal operation, the fire damper is held in the full open position. This is done by a motor mounted on the fire damper assembly. A fire may be detected by either of the two UV detectors within the enclosure. If this happens, the fire stop circuit within the fan controller will close a set of contacts. This energizes the fire damper motor and rotates the damper to the closed position.

Anti-Icing

The anti-icing system is similar to that in the main engine inlet ducts. That is, hot bleed air from the engine is discharged into the inlet duct. There it mixes with the inlet air and raises the temperature above the freezing point. Bleed air flow is regulated as a function of upstream temperature versus a fixed temperature. This maintains an inlet temperature of about 38 °F when anti-icing is selected. This temperature is enough to prevent the formation of ice. It also melts any ice, sleet, or snow entrained in the air.

Exhaust Duct

The exhaust ducts are round, insulated, stainless steel structures. Each duct has a silencer and an IR suppression system. The Model 139 uses a BLISS-type IR suppression system similar to the ones used on the CG-47 main engines. Because of their small size and low gas flow rate, they do not require eductors as do the main exhaust ducts. The exhaust ducts from the No. 1 and No. 2 engines run parallel to the main engine ducts in the exhaust stacks. The duct from the No. 3 engine (figure 8-40) traverses the ship and

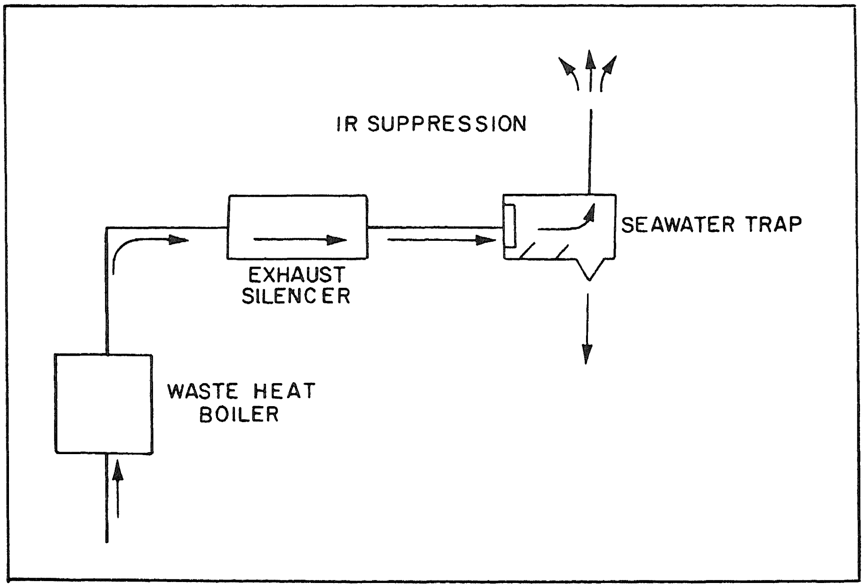

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Figure 8-40.—No. 3 exhaust configuration.

discharges from the port side on the 01 level aft.

SILENCERS.—The silencers have sound deadening material. They are encased in a perforated stainless steel sheet cylinder. This is suspended in the center of the exhaust duct. This unit with the duct wall insulation provides the required sound reduction to meet the airborne noise requirements.

IR SUPPRESSION.—The purpose of the IR suppression system is to reduce the exhaust gas temperature. This is done before it is discharged to the atmosphere. This minimizes heat sensing of the ship by other vessels and aircraft. The system has a manifold in the exhaust duct. Through this, seawater is sprayed into the exhaust gas stream. The spray manifolds for the No. 1 and No. 2 engines are located near the duct exits. The manifold for the No. 3 engine is located at the entrance to the green water trap. This system is not used on the Model 139; a BLISS cap is used on these sets.

GREEN WATER TRAP.—Because of the low location of the No. 3 engine exhaust duct exit relative to sea level, green water can enter the duct exit during high sea states. To stop the seawater flowing through the exhaust system, a tank is located in the duct near the exit (figure 8-40). Any water that enters the duct is trapped in the tank and drained overboard.

GTGS FIRE STOP AND CO_2 SYSTEM

The Allison 501-K17 is protected from damage if a module fire alarms. Two UV detectors are used to sense a fire condition in the engine enclosure. Only the engine enclosure is protected by the installed CO_2 system. The UV sensors and signal conditioners used on the GTGS are similar to the type used on the LM2500. The two sensors are mounted in the enclosure near the compressor inlet. The signal conditioners are mounted in the alarm terminal box located on the generator end of the base. The fire stop logic is controlled by the module cooling fan controller.

FIRE STOP LOGIC (MODEL 104)

When a fire is detected in the module of the Model 104 GTGS, a signal is sent to the fire shutdown relays.

The following actions then occur.

1. A 5-second delay occurs. This prevents any stray signals from causing a fire stop. The fire condition must exist for these 5 seconds.
2. After the 5-second delay, the following actions occur.

   a. Primary CO_2 is released.
   b. A stop command is sent to the LOCOP.
   c. The module fire damper is closed.
   d. The cooling fan is stopped.
   e. Ship's service LP air is ported to the 5th- and 10th-stage bleed air valves to keep them closed.
   f. Fire alarms are activated at the damage control console (DCC), EPCC, and the summary alarm at the switchboard.

3. The stop command to the LOCOP closes the fuel valve. When the GTGS rpm is below 12,780 rpm, the 14th-stage bleed air valve is closed.
4. Door interlocks are provided to prevent CO_2 discharge if the engine section module doors are open.

FIRE STOP LOGIC (MODEL 139)

The Model 139 fire stop is also controlled by the cooling fan controller. The fire stop sequence is different from that on the Model 104. The following actions occur if a fire is detected by the UV sensors.

1. The cooling fan(s) stop(s), if running.
2. A 20-second delay is activated. The fire signal must remain active during this 20 seconds.
3. After 20 seconds the following actions occur.

   a. A stop command is sent to the LOCOP.
   b. Ship's service LP air is ported to the 5th- and 10th-stage bleed air valves to keep them closed.
   c. The fire dampers are closed.

d. Primary CO_2 is released.

e. Fire alarms are activated at the DCC, EPCC, and the switchboard.

4. The LOCOP stop command closes the engine fuel valve. When the engine drops to 12,780 rpm, the 14th-stage bleed air valve closes.

CO_2 SYSTEM DESCRIPTION

The primary system has two 50-pound CO_2 cylinders (one master and one slave), two pressure switches, and two high-volume, low-velocity nozzles. The CO_2 cylinders are mounted in racks adjacent to the module. The pressure switches are located in the piping system. One is outside and the other is inside the enclosure. The nozzles are mounted on the air intake assembly.

Normally the primary bank is activated by fire stop logic. The primary bank can also be activated manually at the bank or remotely from the pull box. When the two pressure switches are operated by CO_2 pressure in the header, a CO_2 release alarm is activated locally and at the DCC. The summary alarm at the switchboard is also activated. Once released, CO_2 discharge cannot be stopped. The primary discharge is at the rate of 200 lb/min.

The secondary system has three 50-pound CO_2 cylinders (one master and two slave) and two high-volume, low-velocity nozzles. These are connected by a common piping system. The secondary bank must be released manually at the bank. The secondary system is not equipped with monitors or alarms. Once released, CO_2 discharge cannot be stopped. The secondary discharge is at the rate of 67 lb/min.

SUMMARY

In this chapter we have discussed the construction and operation of the Model 104 and Model 139 GTGSs used on the Allison 501-K17 engine. We have discussed the construction of the engine, its systems, and its control circuits. We have also discussed the reduction gear, generator, and support systems. After studying this material and completing the associated NRCC, you should be able to start qualifying as an operator of the Allison 501-K17. If your ship does not use these generators for electric power generation, you should know how GTs are used in constant speed applications.

Chapter 12 will also give you information to help you understand shipboard electrical equipment. GSE is rapidly becoming one of the major rates in the field of shipboard power generation and distribution. To become a competent EPCC operator, you must know not only the GTGS, but also the electric plant of the ship.

Remember, before you attempt to operate any ship's system, but especially one as important as a generator, follow all EOSS procedures. This will help prevent any major casualty from occurring because of operator error.

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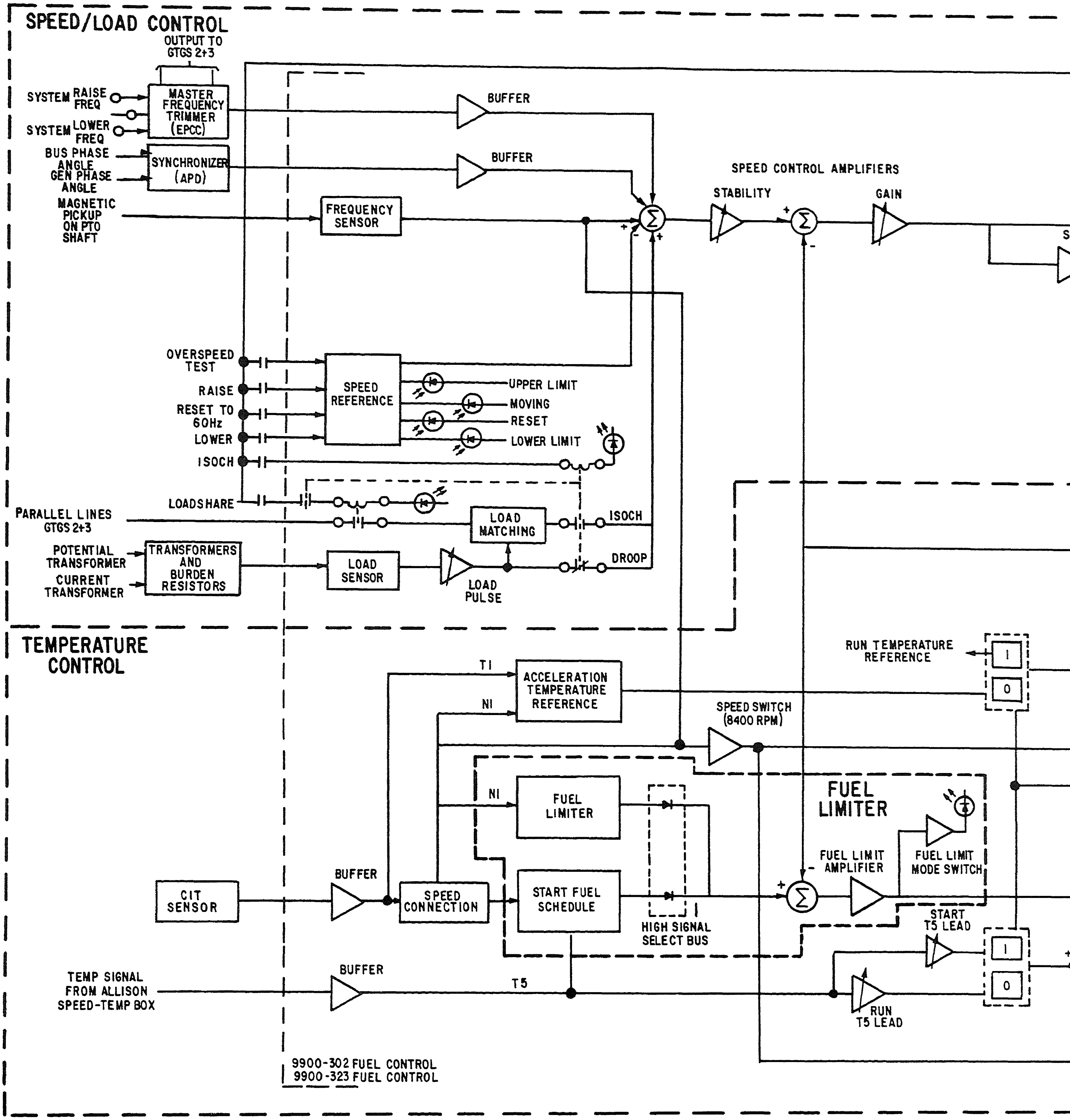

SPEED/LOAD CONTROL
OUTPUT TO GTGS 2+3
SYSTEM RAISE FREQ
SYSTEM LOWER FREQ
MASTER FREQUENCY TRIMMER (EPCC)
BUS PHASE ANGLE
GEN PHASE ANGLE
SYNCHRONIZER (APD)
MAGNETIC PICKUP ON PTO SHAFT
FREQUENCY SENSOR
BUFFER
BUFFER
SPEED CONTROL AMPLIFIERS
STABILITY
GAIN
OVERSPEED TEST
RAISE
RESET TO 60Hz
LOWER
ISOCH
LOADSHARE
SPEED REFERENCE
UPPER LIMIT
MOVING
RESET
LOWER LIMIT
PARALLEL LINES GTGS 2+3
LOAD MATCHING
ISOCH
DROOP
POTENTIAL TRANSFORMER
CURRENT TRANSFORMER
TRANSFORMERS AND BURDEN RESISTORS
LOAD SENSOR
LOAD PULSE
TEMPERATURE CONTROL
RUN TEMPERATURE REFERENCE
T1
ACCELERATION TEMPERATURE REFERENCE
N1
SPEED SWITCH (8400 RPM)
N1
FUEL LIMITER
FUEL LIMITER
FUEL LIMIT AMPLIFIER
FUEL LIMIT MODE SWITCH
CIT SENSOR
BUFFER
SPEED CONNECTION
START FUEL SCHEDULE
HIGH SIGNAL SELECT BUS
START T5 LEAD
TEMP SIGNAL FROM ALLISON SPEED-TEMP BOX
BUFFER
T5
RUN T5 LEAD
9900-302 FUEL CONTROL
9900-323 FUEL CONTROL

CHAPTER 9

ENGINEERING CONTROL SURVEILLANCE SYSTEM OPERATION (SPRUANCE CLASS)

Up to this point we have discussed operation, construction, and control of the gas turbine engineering plant from the local station. One of the revolutionary aspects of the gas turbine plant, though, is its ability to be operated from a central, remote location. This central point is known on all classes of gas turbine ships as the central control station (CCS). The CCS is the primary control watch station for operating nearly all major engineering equipment. Systems that are not controlled in the CCS may at least be monitored from there. This allows for reduced watch standing outside the CCS as opposed to older ships that required watch standers throughout the plant. Also, the EOOW and propulsion, electrical, and damage control watch standers have a quicker look at all vital parameters associated with plant operation.

Currently, two major designs exist for gas turbine CCSs; one for the *Perry* class frigates and one for *Spruance, Kidd*, and *Ticonderoga* classes. In this chapter we discuss the *Spruance* class CCS and point out the modifications made for the *Kidd* and *Ticonderoga* class CCSs. In the next chapter we will discuss the *Perry* class CCS.

The CCS is manned 24 hours a day either in port or at sea. At sea it is normally manned by an EOOW (either an officer or senior enlisted), a propulsion and auxiliary control console (PACC) operator (usually a senior GS petty officer), an EPCC operator (usually a petty officer GSE or EM), and a DCC operator (normally a Hull Technician). A fuel king will monitor the fuel system control console (FSCC) when necessary. Normally, inport watch in the CCS is stood by a single watch stander, who is usually a qualified engineering petty officer. At some point, you, as a GSE petty officer, will stand watch in the CCS. Also, GSEs maintain the control consoles in the CCS as one of their primary duties. Therefore, you should become familiar with all operations that may occur in the CCS.

After reading this chapter and completing the associated NRCC, you should have a good understanding of the function of the CCS. You should also know what operations each watch stander is responsible for and the control each has over these operations. We will also discuss some of the basic circuits involved in the consoles.

This material is meant for training purposes only. It is not meant to replace the EOSS or technical manuals.

With the help of an experienced GSE and by using the knowledge gained in this chapter, following the EOSS, and completing PQS requirements, you should have no problem qualifying in all aspects of CCS operations.

PROPULSION CONTROL

The PACC is a five-bay console (figure 9-1). The primary purpose of the PACC is to house the controls and status indicators of the four GTEs and all the auxiliary equipment for operating the main GTEs for both engine rooms. The operator, when seated facing the PACC panels, is facing the bow of the ship. All the controls and indicators on the two left bay panels correspond to the equipment in engine room No. 1 which drives the port shaft of the ship. All the controls and indicators on bay panels No. 3 and No. 4 are related to the equipment in engine room No. 2 which drives the starboard shaft of the ship. The controls and indicators on bay front panel No. 5 are directly related to the ship's

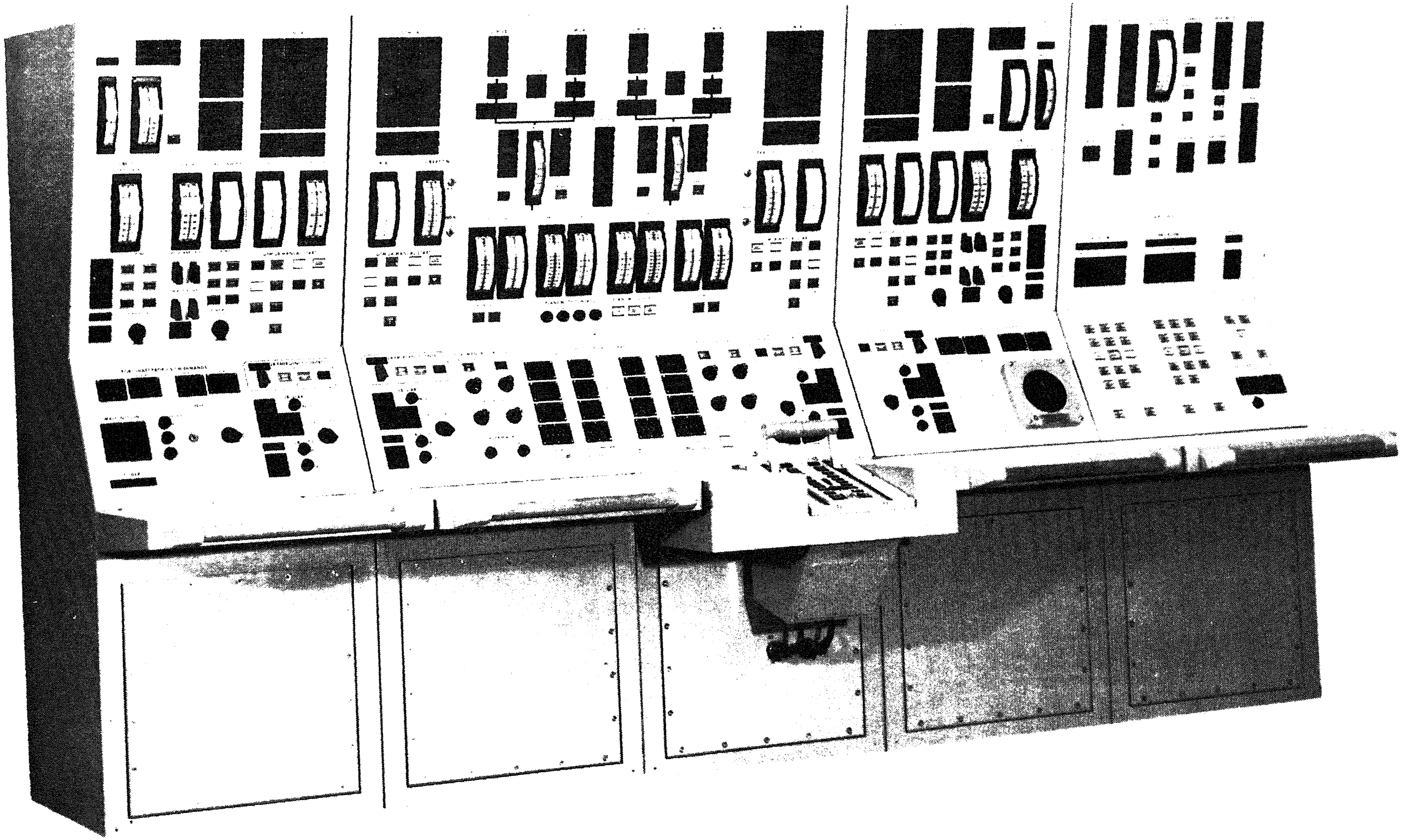

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Figure 9-1.—Propulsion auxiliary control console (PACC).

auxiliary subsystems and the GTM/GTG bleed air systems.

PACC FRONT PANELS

The following are descriptions of the eight front panels on the PACC.

● Panel A of figure 9-2 is the engine No. 2 panel and is divided into five major functions for engine room No. 1. A detailed view is shown in figure 9-3 (a foldout at the end of this chapter). By comparing these panels with those of the local console discussed in chapter 6, you will see the similarities; therefore, we will NOT discuss each indicator in this chapter. First on the panel: the RDCN GEAR LUBO section has an alarm indicator and a meter. Second: the CRP section has six alarm indicators, a meter, and a control switch. Third: the LUBE OIL system has two meters, six alarm indicators, three status indicators, six pump switch/status indicators, and a manual-automatic control switch. Fourth: the FUEL OIL system has 9 alarm indicators, 12 status indicators, 4 meters, 4 valve control switches, a manual-automatic control, 6 pump switch/status indicators, and 2 station-in-control status indicators. Fifth: the GTM 2B section has 30 alarm indicators, 9 status indicators, 4 meters, and the GTM 2B MANUAL START controls with 12 switch/status indicators.

● Panel B of figure 9-2 is the engine No. 2 demands panel and is divided into six sections. Figure 9-4 shows a detailed view. First, the thumbwheel controlled demand display (PORT SHAFT PROPULSION DEMANDS) of various conditions that exist within the propulsion system; second, the GTM 2B EMERGENCY CONTROLS; third, a MALFUNCTION section with ten alarm indicators (these alarm indicators inform the operator of malfunctions within the propulsion local control console (PLCC) or the PACC); fourth, the POWER display with an alarm and status lamp; fifth, the PACC TEST section for testing all the PACC alarm and status lamps and the siren, horn, and bell; sixth, the GTM 2B START/STOP section with a three-position start/stop mode selector switch, an initiate start pushbutton, eight start sequence status/alarm lights, a stop initiate pushbutton,

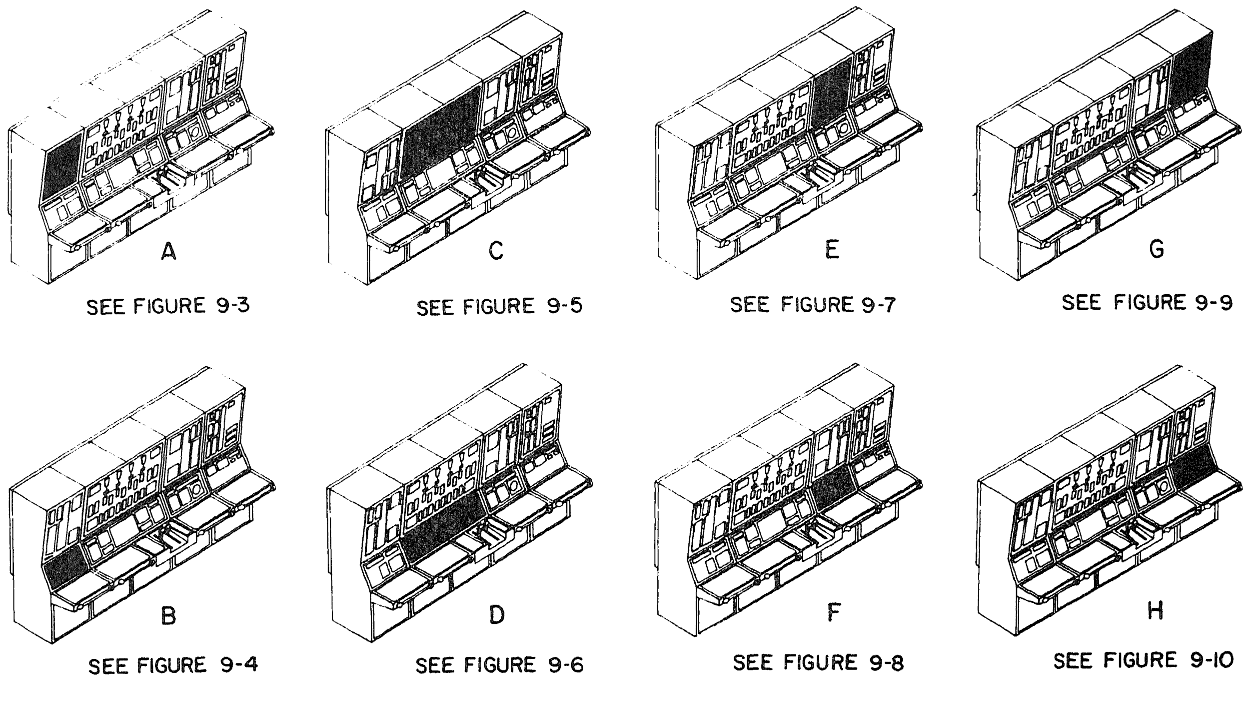

Figure 9-2.—PACC—panel identification.

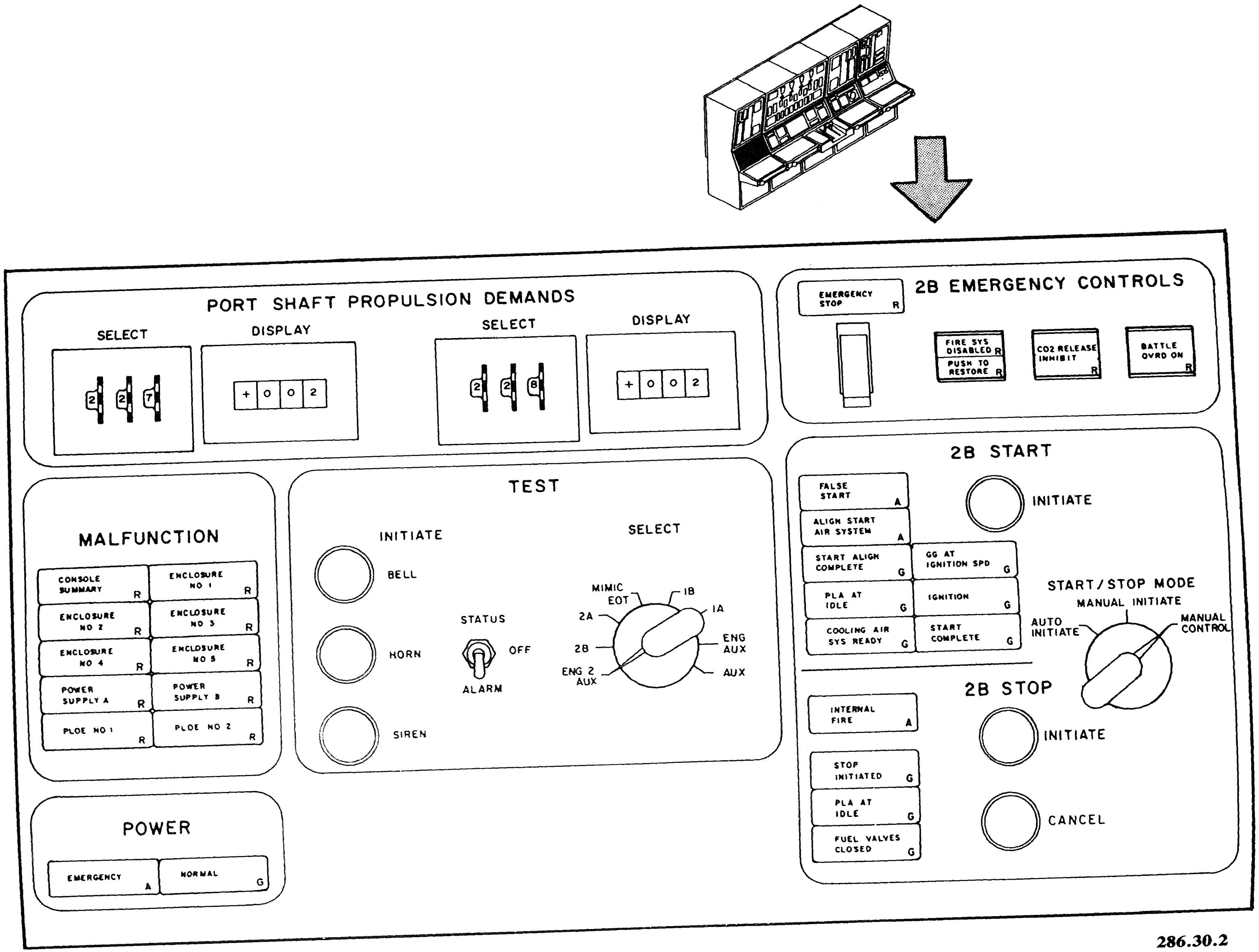

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Figure 9-4.—PACC—engine No. 2 demands panel.

a cancel stop pushbutton, three stop sequence indicators, and an internal fire alarm indicator.

● Panel C of figure 9-2 is called the MIMIC panel because it provides a schematic representation of the four GTMs, clutches, reduction gears, and shafts. Figure 9-5 (a foldout at the end of this chapter) shows a detailed view. The left side of the MIMIC panel contains the alarm/status indicators and manual start switches/indicators for the GTM 2A, PLA and vibration meters, and vibration select switches for GTM 2A and 2B. The right side of the MIMIC panel is identical to the left but labeled for GTM 1A and 1B. The main center part of the MIMIC panel displays the status of each GTM, which station has control of the individual engine rooms, which engines are connected to the main shaft, the alarms and status indicators for the individual engines, and the automatic mode selectors (PLANT MODE SELECT, PLANT MODE CONTROL, ENGINE SELECT and mode change sequence indicators).

● Panel D in figure 9-2 is called the EOT panel. Its main function is concerned with EOT signals (RPM and PITCH signals) for both engine rooms. Figure 9-6 (a foldout at the end of this chapter) shows a detailed view. The extreme left and right portions of the panel have the GTM 2A and GTM 1B EMERGENCY CONTROLS and START/STOP sections. The START/STOP section has a start initiate pushbutton, eight start associated status lights, a stop initiate pushbutton, a cancel stop pushbutton, three stop sequence indicators, and an INTERNAL FIRE alarm indicator.

The EOT section of the EOT panel is divided into two subsections. The left half displays engine room No. 1 (port) RPM and PITCH signals. The right half displays engine room No. 2 (Stbd) RPM and PITCH signals. Both subsections have thumbwheel controls for rpm and pitch. It also has nine acknowledge pushbuttons for answering bell alert requests from the pilothouse.

The PORT MANUAL THROTTLE section contains a throttle auto/manual mode select switch, the manual throttle controls for both the GTM 2B and GTM 2A, a sea state control ON/OFF switch, a sea state adjust control, and a control for the port propeller pitch. The ALARM ACK section has two pushbuttons to acknowledge any PACC alarm or warning signal. The STBD MANUAL THROTTLE section has the same controls and indicators as the port manual control except they are for engine room No. 2, GTM 1B and GTM 1A. The THROTTLE TRANSFER section has pushbuttons for control/display of the station in control of the throttle.

● Panel E in figure 9-2 is divided into five major functions for engine room No. 2. Figure 9-7 (a foldout at the end of this chapter) shows a detailed view. The alarm displays, status displays, and controls for functions of engine room No. 2 (MRG, CRP, LUBE OIL, FUEL OIL, and GTM 1A) are identical to those discussed for the engine room No. 1 panel.

● Panel F in figure 9-2 is divided into four major functions. Figure 9-8 (a foldout at the end of this chapter) shows a detailed view. First, the 1A EMERGENCY CONTROLS and alarm displays for the GTM 1A; second, the thumbwheel controlled STBD SHAFT PROPULSION DEMANDS digital display of various conditions that exist within the control system; third, a SPEED CALIBRATION meter that displays the actual speed of the ship; fourth, the GTM 1A START/STOP section, and a matrix chart equating standard orders to knots (speed), shaft rpm, and pitch settings.

● Panel G in figure 9-2, the auxiliary and air panel, displays the status of various ships' subsystems. Figure 9-9 (a foldout at the end of this chapter) shows a detailed view. There are 11 status indicators for the IR suppression (IR SUPPR) system; 10 alarms for the ship's waste heat boiler (WASTE HT BLR) system; 2 meters and 3 valve controls for the STEAM system; 4 alarms and 3 pump control switches for the SEAWATER system; 5 alarm and 4 status indicators and 2 pump control switches for the FRESHWATER system; 7 alarms and 2 status indicators for the HP AIR system; 6 alarms and 2 status indicators for the ship's service (SS) AIR system; 3 alarms for the ship's air-conditioning (AIR COND) system; 4 alarms for the ship's DISTILLING system; 6 alarms for the ship's SEWAGE system; and 2 alarms for the ship's refrigeration (REFRD) system. In addition, the lower section has 18

alarms related to various air temperatures and pressures for each engine room (ENG ROOM 1 and ENG ROOM 2) and GTG 3.

- Panel H in figure 9-2 has switches and valve status indicators for the automatic and/or manual controls related to the bleed air system for each engine room. Figure 9-10 (a foldout at the end of this chapter) shows a detailed view. It also has the five control switches for prairie/masker air and valve status indicators for the GTG 3. In addition, it has a thumbwheel controlled demand digital display of various conditions that exist within the control system along with a print pushbutton for printing thumbwheel requested information.

THROTTLE CONTROL

Each of the GTs has its own individual main fuel control to which is attached a POWER LEVER actuator. This lever can be compared to the accelerator on an automobile. The power lever rotates in an arc from closed (13 degrees) to full open (about 113 degrees). All references to the position of the power lever are given in percentages that correspond to the PLA. As the PLA is increased, the GT rpm and the resultant ship's propeller shaft rpm are increased.

The speed of the ship is a function not only of the rpm of the propeller shaft, but also is directly related to the pitch angle of the ship's variable pitch propeller. Therefore, any discussion concerning the control of the ship's speed must include both the PLA and the propeller pitch even though they are separate systems.

The PLA actuator is physically located on the GTE. The electrical signal to this actuator is generated in the PLCC and FSEE and is referred to as the PLA command.

The propeller pitch actuator is physically attached to the oil distribution box mounted on the MRG in each engine room. The electrical signal to this actuator is generated in the PLCC and pitch electronics and is referred to as the PITCH command.

There are two methods of providing PLA and pitch commands to the gas turbines. The first is manual throttles (from either the PACC or PLCC) and the second is the integrated throttle control (ITC) from either the PACC or the SCC. There are two methods of communicating desired speed settings from the SCC to the PACC/PLCC. The first is through the standard order EOT and the second is through the digitized EOT.

Manual Throttle/Pitch Control

With control at the PLCC, PLA/PITCH settings are accomplished by positioning the throttle/pitch levers. There is one throttle lever for each GTM with a latching device for operating both levers simultaneously. There is one pitch lever for control of pitch. With control at the PACC, the PLA/PITCH settings are accomplished using rotary potentiometers on the EOT panel. There is one potentiometer for each GTM and one for pitch. Use of manual throttles at PACC bypasses PACC auto throttle circuitry.

Integrated Throttle Control

Integrated throttle control (ITC), or automatic throttle control, is available at the PACC (figure 9-11) or at the SCC. There are two levers, one for each shaft, for simultaneous control of the GTMs and controllable reversible propeller (CRP). These levers can be mechanically latched together to control both shafts simultaneously or unlatched for individual shaft control (figures 9-12 and 9-13).

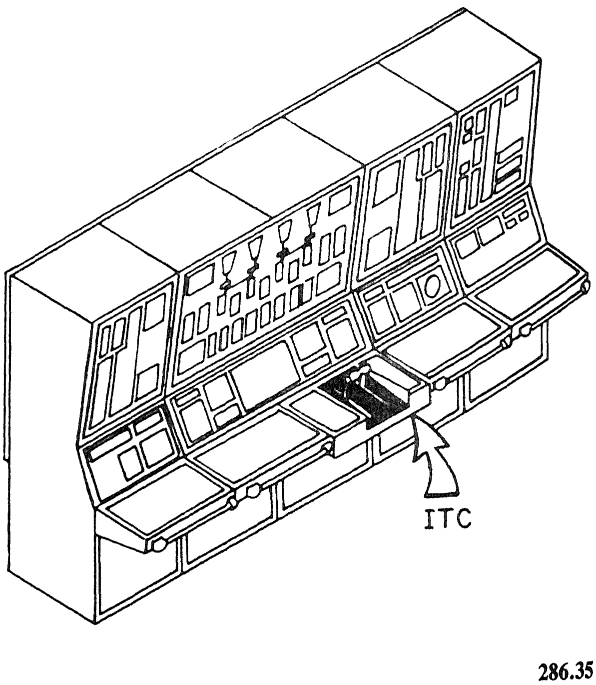

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Figure 9-11.—PACC—ITC location.

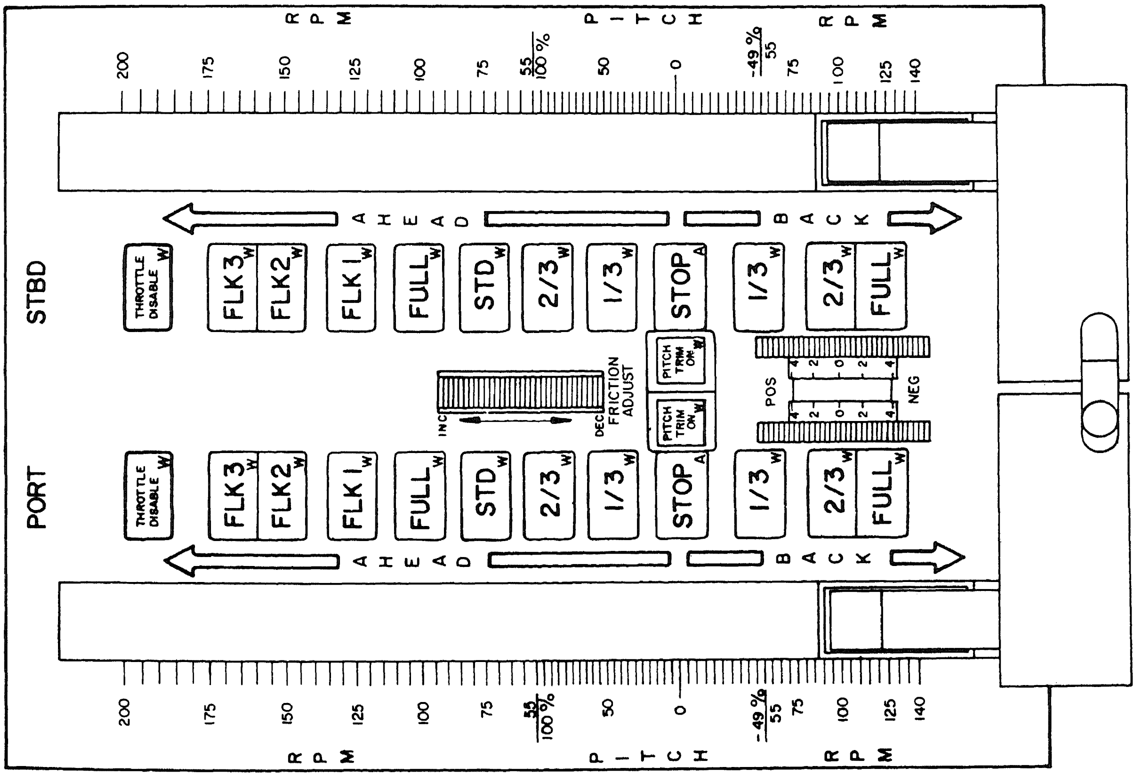

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Figure 9-12.—PACC—ITC.

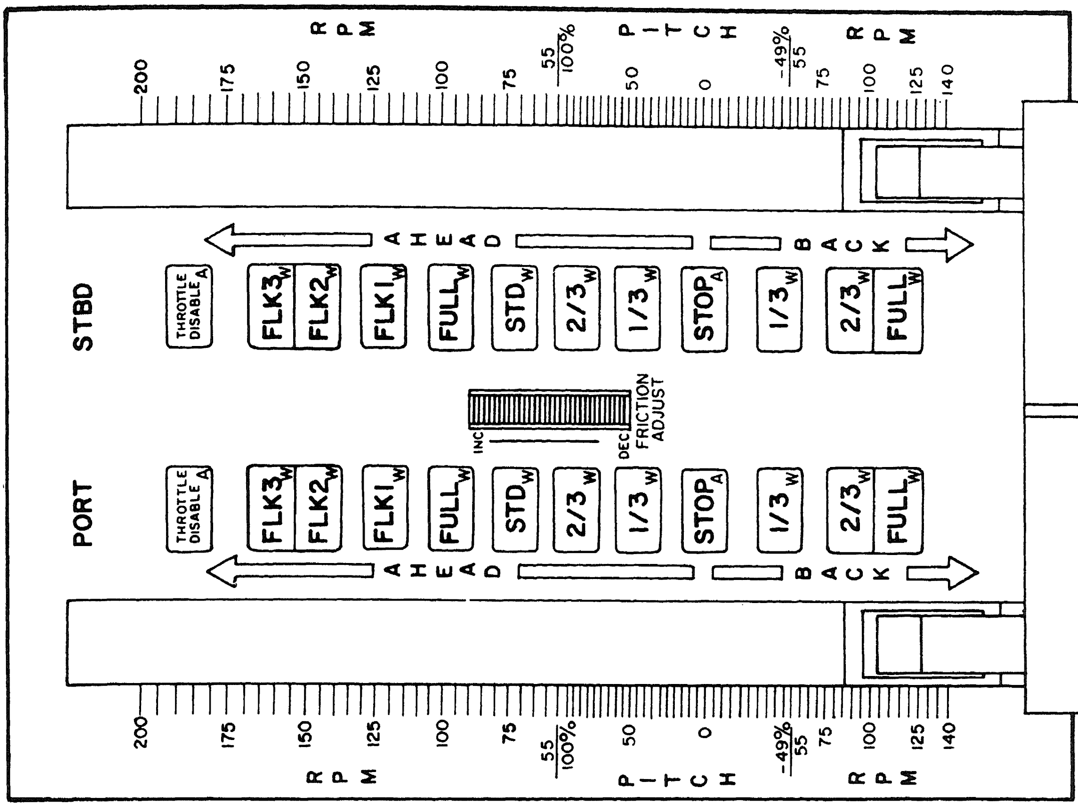

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Figure 9-13.—Ship control console—ITC.

NOTE: The major difference between the two ITCs is that the PACC ITC has provisions for pitch trim, while the SCC ITC does not. Therefore, the two ITCs are not interchangeable. This system is called ITC because the information for both pitch and rpm for an engine room is given by one analog reference voltage. Two references, one for each shaft, are generated by each of the levers at the console (PACC or SCC) that has control.

Table 9-1 shows the rpm and pitch relationship over the range of the throttle lever. In the ahead direction, shaft rpm is held at 55 until propeller pitch reaches 100 percent. After this point, shaft rpm is increased and pitch remains at 100 percent. In the astern direction, shaft rpm is held at 55 until propeller pitch reaches −49 percent. After this point, shaft rpm is increased and pitch remains at −49 percent.

Figure 9-14 is a functional block diagram of the ITC which provides the rpm and pitch integration. The analog reference voltage developed by the ITC levers at the PACC or the SCC is given to three schedulers and one compensation circuit. These are the PLA scheduler, the rpm scheduler, the rpm compensation, and the pitch scheduler.

The PLA scheduler develops an analog voltage proportional to ITC lever position. This scheduler provides a feed forward reference command to the PLA. The reference command gives an approximate position of the PLA on the engine for an rpm setting on the ITC. This schedule is changed depending upon split or full power (one engine or both engines) operation. In split plant operation, the maximum allowed PLA command is 140 rpm. In full power operation, the rpm is allowed to go above 140 rpm. This signal is then delivered to a rate limiting circuit which allows smooth on- and off-line transfers of engines. This is done by preventing PLA command reference from rapidly changing, thus minimizing GTM surging.

Table 9-1.—ITC—RPM-Pitch Relationship

ITC TRAVEL	SHAFT RPM	PROPELLER % PITCH
AHEAD	200	100
	175	
	150	
	120	
	100	
	75	
	55	100
		75
		50
		25
STOP	55	0
		-25
	55	-49
ASTERN	75	
	100	
	125	
	140	-49

286.37

The rpm scheduler works with the PLA scheduler to control shaft rpm. The rpm scheduler develops an analog voltage proportional to ITC lever position. The voltage represents the rpm called for by the ITC lever setting. It is compared with a voltage that represents actual shaft rpm from the shaft tachometer. They are algebraically summed and an error voltage is developed whose magnitude and polarity are related to the error between the commanded and actual rpm. This signal is then passed to the rpm compensation circuit (discussed later). There it is added to or subtracted from the PLA signal to control shaft rpm accurately. The corrected PLA signal command voltage is then sent to the circuitry at

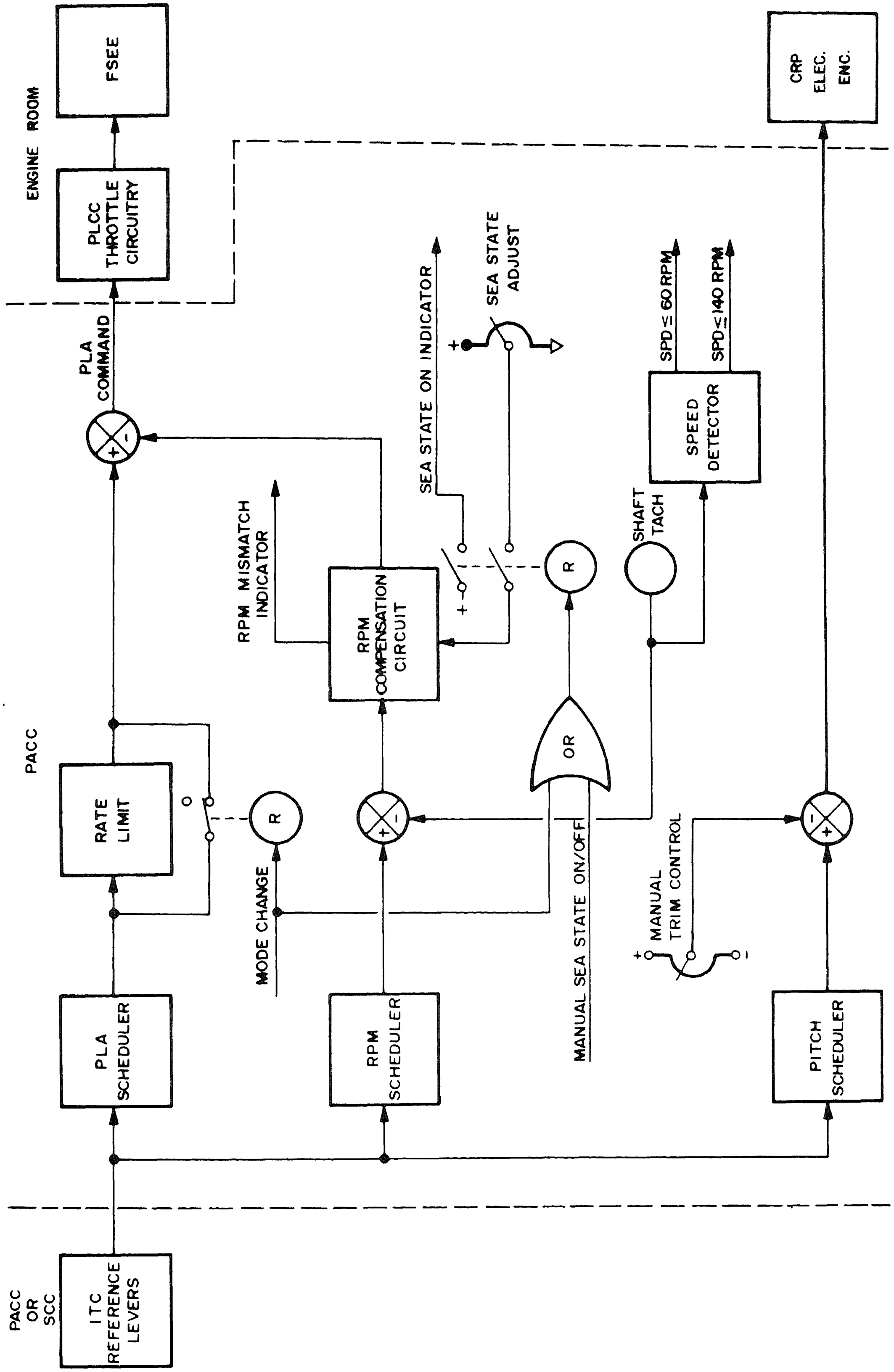

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Figure 9-14.—Functional block diagram of the ITC circuit.

the PLCC and then to the FSEE. Figure 9-15 shows the relative PLA command output for a given ITC lever position.

The rpm compensation circuitry provides for sea state adjustment. A manually operated sea state adjustment is provided with the ITC circuitry at the PACC only. This control allows reduction of the ITC sensitivity to shaft rpm fluctuations caused by sea state conditions. It can decrease the ITC system relative gain from 1.0 down to 0.1. At a setting of 1.0, or sea state off, the ITC will regulate shaft rpm to within a 12-rpm error. As the sea state control is adjusted to lower gain values, the ITC will regulate, but within greater rpm errors. This control is automatically disabled during engine transfer (on-line or off-line) to allow for minimum transfer times. A pushbutton switch/indicator is provided at the PACC for each shaft to indicate SEA STATE ADJUST ON (figure 9-6). An output from the compensation circuit COMMAND RPM MISMATCH is provided to an alarm indicator at the PACC when an error signal of 5 rpm or greater between the command and tachometer persists for more than 1 minute.

The shaft tachometer signal is also used to detect discrete rpm levels. A shaft speed less than or equal to 60-rpm signal is used in the throttle enable and shaft brake logic circuitry. A shaft speed less than or equal to 140-rpm signal is used in the plant mode transfer logic.

The pitch scheduler, shown in figure 9-14, provides a reference voltage to the CRP electronics enclosure. A manually operated pitch trim adjustment for each shaft is provided at the PACC ITC only, although it may be used by the PACC operator when the SCC is in control. The trim control has a range of ±10 percent of the existing pitch over the range of pitch schedule output. A detent is provided at the 0% pitch trim position for ease of operator usage. A PITCH TRIM ON indicator light is provided for each shaft at the PACC (figure 9-12). This indicator is illuminated when the pitch trim control is moved off the 0-percent setting. Figure 9-15 shows the relative pitch command output from a given ITC lever position with the trim adjustment limits.

A COMMAND PITCH MISMATCH alarm indicator is provided at the MIMIC panel of the PACC (figure 9-5). It provides an alarm if the

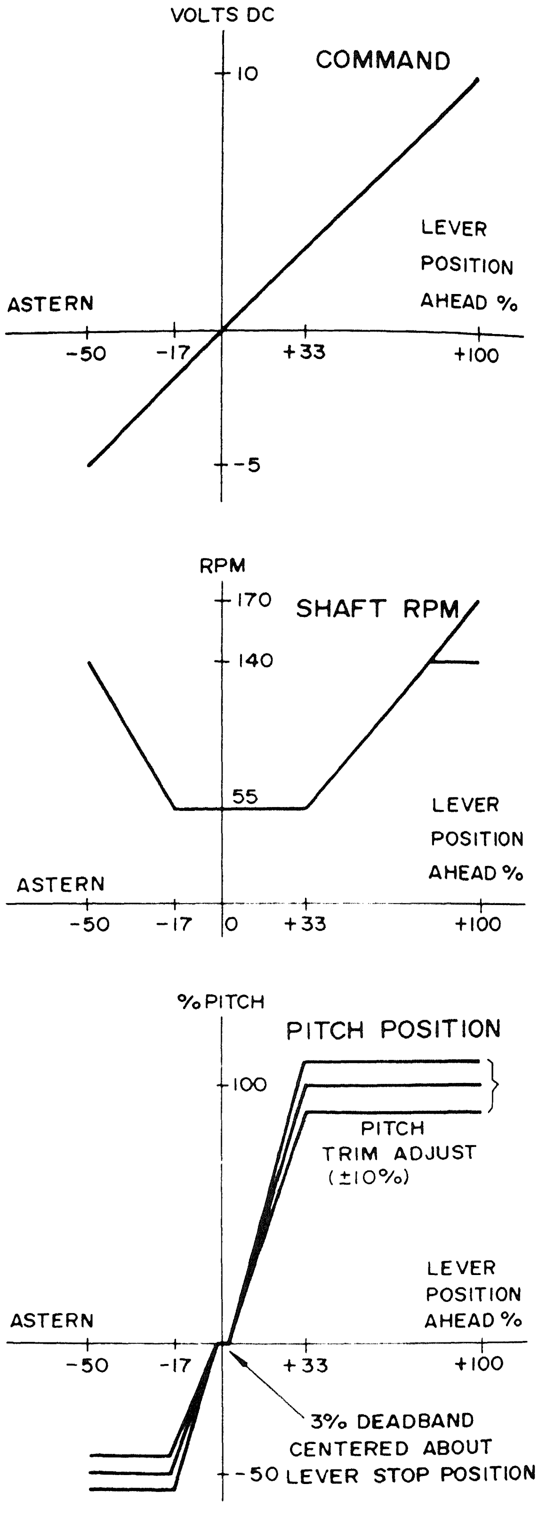

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Figure 9-15.—Relative PLA command output for ITC lever positions.

commanded pitch signal and actual pitch signal disagree by a 5-percent error for 3 minutes.

Throttle Control Transfer

Throttle/pitch control is possible at one of three locations. For the SCC to have integrated throttle control, both the PLCC and PACC must have their remote stations selected. That is, the PLCC must have at least one GTM and EOT control transferred to the PACC. The PACC must have the throttle control transferred to the SCC. See figure 9-16 for the relationship between consoles. At the PLCC only manual throttle and pitch control for their respective GTMs is available. Manual control of an individual GTM may be transferred to the PACC from the PLCC. At the PACC each GTM may be controlled manually by rotary potentiometer controls which operate the same as the lever controls found at the PLCC. Either or both GTMs may then be placed in auto (ITC) control. To transfer throttle control from the PACC to the SCC, both GTMs must be in auto throttle control. The PACC may take throttle control from the SCC at any time. The PLCC may take throttle/pitch control from the SCC or PACC at any time.

Standard Orders

Standard orders originate at the SCC and are used when the PACC has control of the throttles. The SCC operator moves the ITC to the new position and then depresses a STD ORDER ALERT pushbutton. This signal is routed to the PACC and PLCC. At the PACC on the integrated throttle unit (figure 9-12), the new standard order light begins flashing and an audible alarm is sounded. When in automatic mode, the PACC operator responds to the

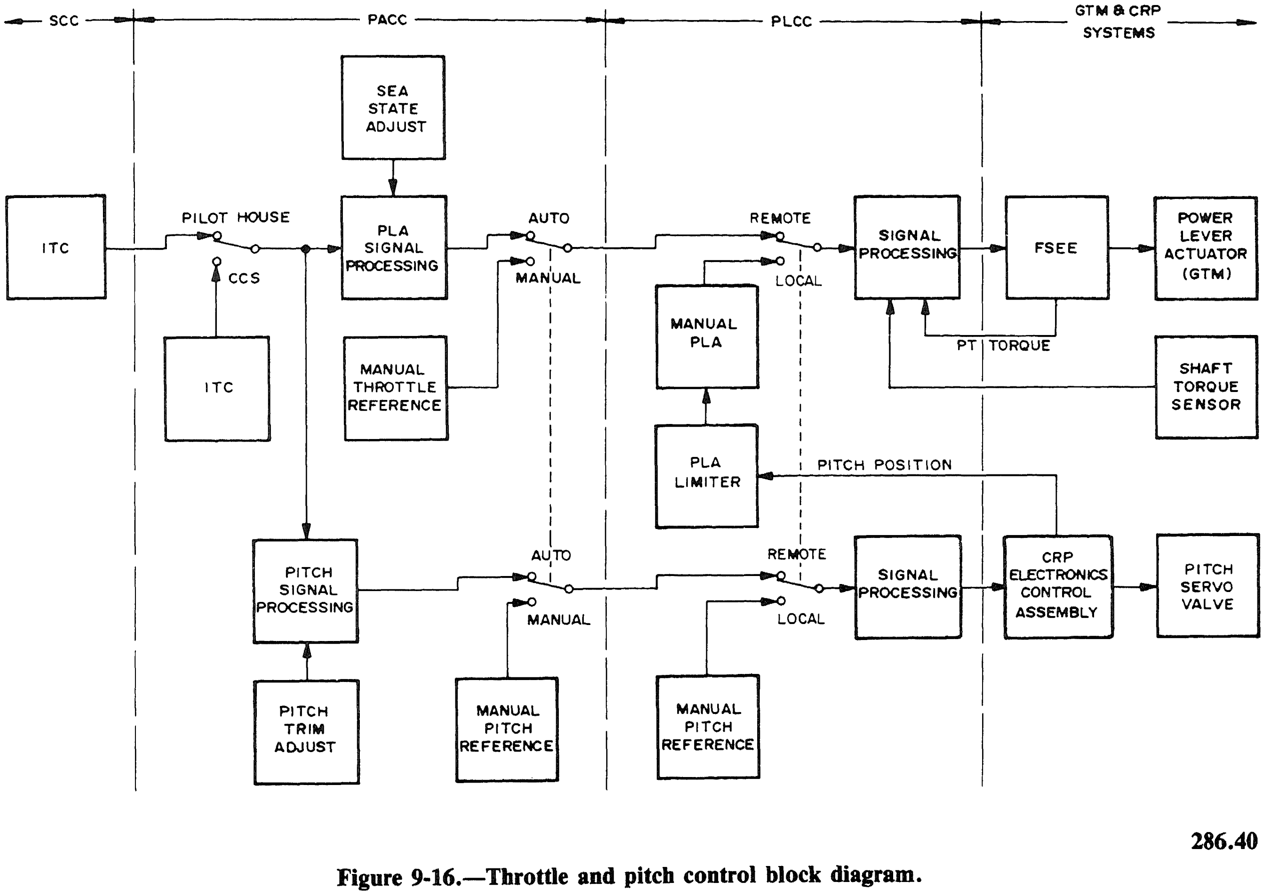

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Figure 9-16.—Throttle and pitch control block diagram.

flashing light by moving the ITC lever to the new position. Then the STD ORDER ACKNOWLEDGE pushbutton (figure 9-6) is depressed. The ACKNOWLEDGE signal causes the flashing light to go to a steady state. The signal generated by the PACC ITC lever movement is processed through the same circuitry that the SCC/ITC signal used. The PACC manual mode of responding to standard orders is slightly different. The SCC operator generates a new standard order by moving the ITC. This signal generates an alarm and a flashing light on the PACC ITC. The PACC operator acknowledges the alarm by depressing the STD ORDER ACKNOWLEDGE pushbutton. Then the operator manually adjusts the two PLA potentiometers and the PITCH potentiometer (figure 9-6) associated with each engine room. The signals from the potentiometers are then routed via hardwire to the PLCC. There they are processed before going to the PLA and PITCH actuators.

Engine Order Telegraph

The EOT system is a digital system used primarily as a backup throttle communications system (figure 9-6). The signals used are (1) RPM ALERT, (2) PITCH ALERT, (3) RPM digital thumbwheel setting, (4) PITCH DIGITAL thumbwheel setting, (5) RPM ALERT ACKNOWLEDGE, (6) PITCH ALERT ACKNOWLEDGE, (7) ship's shaft actual RPM, and (8) propeller actual PITCH. This system is used when the PACC or PLCC is in control of the throttle.

The actual RPM and PITCH are digitally displayed at the SCC, PACC, and PLCC. When the OOD orders the SCC operator to change RPM and/or PITCH, the following events occur. The SCC operator sets the new values of RPM and PITCH on the thumbwheels and then depresses the RPM and PITCH ALERT pushbuttons. These signals are sent to the PACC and PLCC where they appear on the digital displays labeled RPM and PITCH ORDERED. At the same time an audible alarm is sounded and the RPM and/or PITCH ACKNOWLEDGE pushbutton lights begin to flash. When the PACC is in control of the throttle, the operator responds in the following manner. (See figure 9-6.) The operator sets the new RPM and/or PITCH on the thumbwheels and depresses the flashing RPM and/or PITCH ACKNOWLEDGE pushbutton. The light stops flashing and the audible alarm is turned off. The operator then manually changes the proper PLA and/or PITCH potentiometer or moves the ITC lever.

The signals from the potentiometer are sent via hardwire to the PLCC and are then sent to the PLA and/or PITCH actuator. As the shaft RPM and PITCH change, they are fed back into each console as ACTUAL RPM and ACTUAL PITCH values.

GAS TURBINE MODULE CONTROL AND MONITORING

Each GTM has three possible start/stop modes that are operator selectable. The three start/stop modes are MANUAL, MANUAL INITIATE, and AUTO INITIATE (plant mode). Auto initiate is available only at the PACC.

MANUAL CONTROL MODE

The manual control mode calls for the operator to generate the start or stop commands at each and every step of the sequence at the appropriate times. Sequencing of these manual controls is the same as the time sequential flow charts provided for manual initiate start/stop. Manual start/stop control is available at the PLCC or PACC. It is discussed in detail in chapter 6 of this manual. (See figures 9-3, 9-5, and 9-7 for the manual control pushbuttons on the PACC.)

MANUAL INITIATE MODE

Manual initiate mode consists of starting and stopping the GTM in a semiautomatic mode. In this mode, the engine will start or shut down automatically. That is, the control electronics at the PLCC will automatically sequence the start or shutdown steps required. This mode is semiautomatic because the clutch and brake operation to couple the GTM to the MRG must be done manually. Manual initiate mode is available at either the PLCC or PACC.

As discussed in chapter 6, the operator must be aware of the condition of the plant before initiating a start. If one engine on a shaft is already on line and the clutch is engaged, no action is required by the operator except to initiate the start. If the shaft is static, no engine is on line and the shaft is not turning. Then the operator must first engage the clutch on the engine to be started. This procedure is unique to DD-963/DDG-993 class ships and is referred to as static (dead) shaft pickup. Static shaft pickup can be used with manual control mode and manual initiate mode. However, it is not used for plant mode as there is no plant mode for secure to split plant or full power.

We will not discuss the engine start sequence in the manual or manual initiate mode in this chapter. These sequences were covered in detail in chapter 6.

PLANT MODE (AUTOMATIC)

Plant mode control electronics is located at the PACC. A layout of pushbuttons and indicators for plant mode change is shown in figure 9-5. The control works with the start/stop logic at the PLCC. In plant mode control, the operator can start or shut down main engines in both engine rooms without using the individual GTM start/stop controls. The plant mode control is used when all the following systems are aligned as indicated below.

- GTM START/STOP MODE in AUTO INITIATE
- THROTTLE CONT in AUTO
- Clutch/Brake in AUTO BRAKE CLUTCH MODE
- Air CONTROL MODE in AUTO

With the above systems in auto and the propulsion plant in one of three propulsion configurations (secure, split plant, full power), plant mode control is enabled. Secure plant mode is defined as no GTMs driving either propeller shaft. Split plant mode is defined as one GTM per engine room driving a shaft. Full power mode is defined as both engines per engine room driving a shaft. With plant mode control enabled, the following mode changes can be performed.

- Split plant to full power (figure 9-17)
- Full power to split plant (figure 9-18)
- Full power or split plant to secure (figure 9-19)
- Change engine (split plant to split plant)

NOTE: Secure to split plant is not available except on CG-47 class ships.

The following status indicators are found on the PACC MIMIC panel (figure 9-5).

1. OUT OF SERVICE—the key switch at the PLCC is in the out of service position. This prevents starting of the GTMs.
2. SECURED—the auxiliary systems are not running or are not ready. These systems are fuel oil, lube oil, MRG, and bleed air.
3. STANDBY—the auxiliary systems are ready. The systems and conditions required are
   a. fuel oil—header pressure greater than 40 psig,
   b. lube oil—header pressure greater than 9 psig,
   c. MRG—turning gear disengaged, and
   d. bleed air—header pressure greater than 40 psig.
4. RUNNING—the GTM has N_{GG} greater than 4300 rpm, $T_{5.4}$ greater than 400°F, and clutch disengaged.
5. ON LINE—the engine is running and the clutch is engaged.

Split Plant to Full Power

Figure 9-17 (a foldout at the end of this chapter) shows the sequence of events when plant mode control is used to place the two standby GTMs on line with the two GTMs already on line. The AND logic at the top center of the flow chart shows the five conditions needed to begin a request for full power from a split plant mode. These five conditions are as follows.

1. GTM start/stop mode is in AUTO INITIATE.
2. Throttle control is in AUTO.
3. SPLIT PLANT mode is shown.
4. Start mode change is commanded.
5. FULL POWER mode is selected.

When these conditions are satisfied, the MODE CHANGE STARTED indicator (figure 9-5) is illuminated and a signal is sent to the throttle control circuitry. Control now enables the four AND logic blocks and automatically selects the two GTMs in standby mode to be started. If either engine is SECURED or OUT OF SERVICE, the mode change logic will be automatically reset and the mode change will be terminated. After both engines are selected, the ENGINE SELECT pushbutton switch/indicator for each will be illuminated at the PACC. Control now flows through both OR logic blocks to the AND logic located at the flow chart center. The AND logic is satisfied and control issues start commands to start circuitry at each PLCC for the selected GTMs. Control now waits for both engines to reach running state. If a false start is detected, the plant mode control will display the RESTART or SELECT ALTN (alternate) indicator and sound an audible alarm. The control then enters a 20-second delay. This allows the operator time to activate the ENGINE RESTART pushbutton and try to restart the same engine again. If the 20 seconds elapses, the MODE CHANGE RESET indicator will be illuminated. Then the operator must manually reset the control with the PLANT MODE CONTROL RESET pushbutton. After receiving RUNNING signals for both GTMs, control will issue commands and illuminate indicators as follows.

1. Engage clutch command
2. Release brake command
3. ENGAGE CLUTCH display
4. RELEASE BRAKE display
5. FULL POWER mode display
6. GTMs RUNNING display

Control now waits for signals from MRG control indicating that the clutches are engaged. At this point, the GTM ON-LINE indicators are illuminated. The plant mode control then enters a 45-second time delay to allow time for the GTM throttle to stabilize. After the 45 seconds has elapsed, the MODE CHANGE COMPLETE indicator will be illuminated for 15 seconds. Then the plant mode logic is automatically reset.

Full Power to Split Plant

This mode change allows the operator to select one GTM in each engine room to remain on line. The nonselected GTM clutches are automatically disengaged and the GTM status indicates RUNNING. The flow chart on figure 9-18 (a foldout at the end of this chapter) shows the sequence of events that takes place when changing modes from full power to split plant. The AND logic at the top center shows the five conditions needed to begin the mode change. These five conditions are as follows.

1. GTM start/stop mode is in AUTO INITIATE.
2. Throttle control is in AUTO.
3. FULL POWER mode is shown.
4. Start mode change is commanded.
5. SPLIT PLANT mode is selected.

When these five conditions are satisfied, the MODE CHANGE STARTED and SELECT ENGINE indicators are illuminated. A signal is also sent to the throttle control circuitry in both shaft card cage assemblies in the PACC (figure 9-19). This signal disables the RPM/PLA rate limit electronics. This allows minimum engine transfer time. The SEA STATE ADJUST is enabled after the mode change is completed. Control now enables the operator to select one GTM to remain on line in each engine room. The flow chart shows the three conditions needed at each AND logic to select engines. These three conditions are as follows.

1. Plant mode control START MODE CHANGE is started.
2. Engine ON LINE is shown.
3. Engine select command is started.

When the conditions are met, an ENGINE SELECT display shows which engines have been selected. Control now flows through both OR logics to the AND logic located at the flow chart center. The following four conditions are needed before continuing.

1. One GTM selected in engine room No. 1
2. One GTM selected in engine room No. 2
3. Shaft No. 1 rpm less than 140
4. Shaft No. 2 rpm less than 140

Because of the power limits in the split plant mode, shaft rpm of 140 or more cannot be requested. When the four conditions are satisfied,

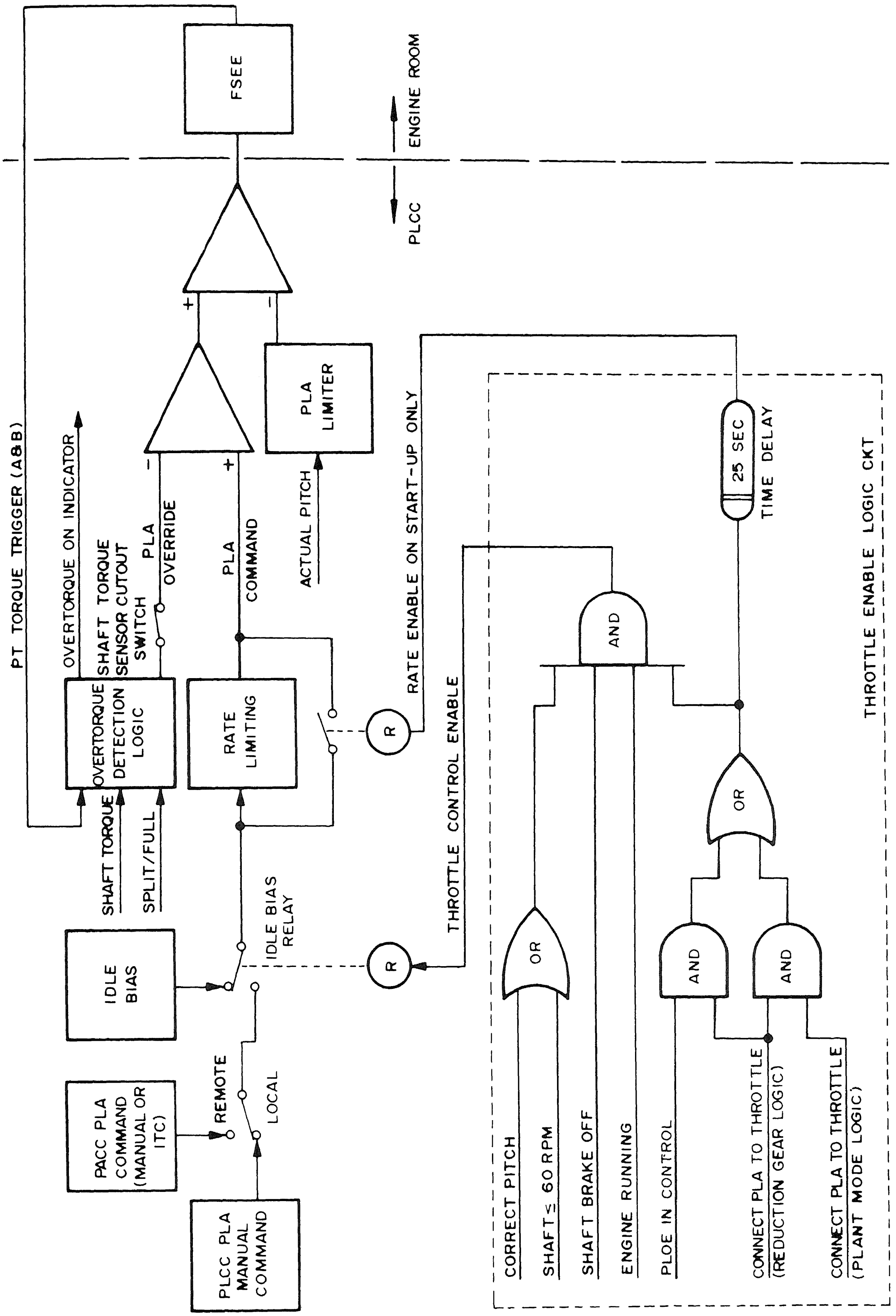

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Figure 9-19.—PLA processing.

two commands are sent to each PLCC. First, the throttle control for each nonselected GTM is commanded to connect PLA to idle. At the same time, the change mode control will illuminate the PLA AT IDLE indicator at the PACC. Second, a stop command is sent to the stop sequencer. The stop control will begin the same stop sequence as for the stop command issued in the manual initiate mode. The plant mode change control now waits for GTM control at each PLCC to signal that engines are at idle speed. Control then issues a command to disengage clutches and illuminates the DISENGAGE CLUTCH indicator at the PACC. After both MRG control circuits have shown that the clutches are disengaged, the following actions are begun.

1. The 45-second timer is started.
2. SPLIT PLANT display is illuminated.
3. GTM RUNNING is displayed for non-selected engines.

Control then delays for 45 seconds to allow time for the GTM throttles to stabilize. After the 45 seconds has elapsed, the MODE CHANGE COMPLETE indicator is illuminated for 15 seconds. Then the plant mode logic is reset. The stop sequencer begins a 5-minute idle speed cooldown period for the engines. After the 5 minutes has elapsed, the engines will be secured, the brake will be engaged, and the GTM SECURED indicator at the PACC is illuminated.

Full Power or Split Plant to Secure

This plant mode change is similar to the full power to split plant mode change just discussed. The flow chart in figure 9-20 (a foldout at the end of this chapter) shows the sequence of events that takes place when changing to the secure plant mode. The AND logic at the top center shows the five conditions needed to begin the mode change. These five conditions are as follows.

1. GTM start/stop mode is in AUTO INITIATE.
2. Throttle control is in AUTO.
3. FULL POWER or SPLIT PLANT mode is shown.
4. Start mode change is commanded.
5. SECURE mode is selected.

When these conditions are satisfied, two commands are issued to each GTM: connect PLA to idle and stop engines. Also, the MODE CHANGE STARTED and PLA AT IDLE indicators are illuminated. Control then waits for all engines to reach idle speed. At this point, the clutch disengage command is sent to all MRG control circuits. After the clutches are disengaged, the following actions are begun.

1. The 45-second timer is started.
2. SECURE plant mode display is illuminated.
3. GTM RUNNING indicator lights are illuminated.

Control enters a 45-second delay and will continue from this point in the same manner as discussed in the last topic.

Change Engines

The change engines command allows for GTMs in the same engine room to be rotated on and off line automatically when in the split plant mode. The change engine mode begins when a split plant exists and the START MODE CHANGE and CHANGE ENGINE pushbuttons are depressed simultaneously. Control will then request the operator to select the engine or engines to be placed on line. The operator may now select to rotate engines in one or both engine rooms. After one engine is selected, a 10-second delay is entered. This allows time for the operator to select a second engine if desired. After the 10 seconds has elapsed, control will enter the same mode change sequence as the split plant to full power change. After the engine or engines are placed on line, a 30-second delay is entered. This allows time for any transfer disturbance to settle out. After this delay, the engine or engines to be rotated off line enter the same mode change sequence as the full power to split plant change.

During any of the mode change sequences discussed, if a brake release command is issued by the plant mode logic to a GTM that is running and the brake is not released within 20 minutes, the RELEASE BRAKES indicator flashes and an audible alarm is sounded.

ELECTRIC PLANT CONTROL CONSOLE

The EPCC (figure 9-21) provides the console operator with automatic control logic and

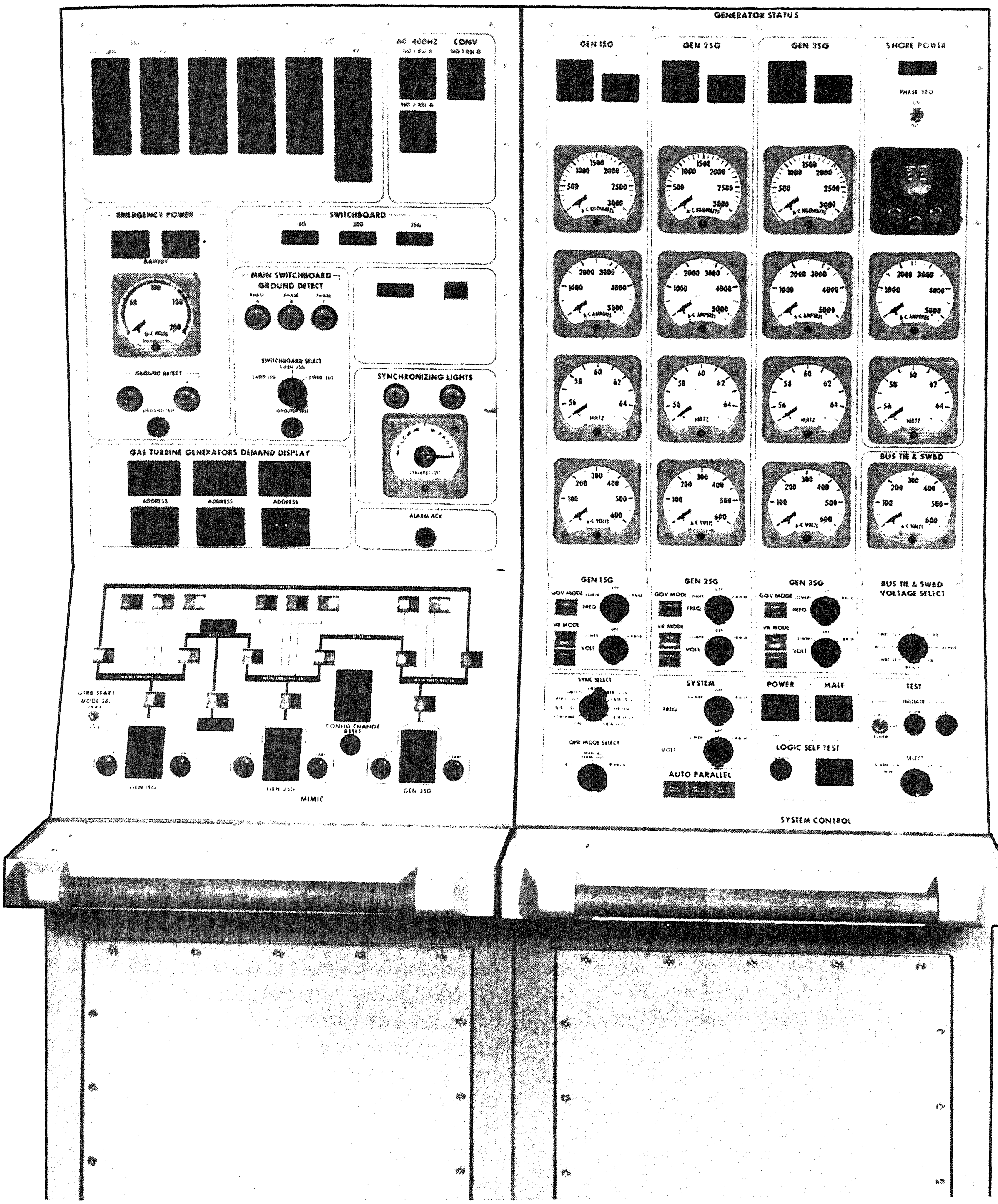

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Figure 9-21.—Electric plant control console.

electric plant status and performance monitoring displays. The EPCC also contains manual control for operating the ship's electric power generating and distribution system. Thus, the EPCC operator can start and stop any GTG, raise and lower voltage and frequency, open and close generator breakers (GBs) and bus tie breakers (BTBs), and monitor the entire electric plant operation at the EPCC. The EPCC displays and controls are located on four front panels (figure 9-22): the MIMIC and distribution control panel, the system control panel, the generator status panel, and the alarm/status panel. Each panel is discussed in the following paragraphs.

MIMIC AND DISTRIBUTION CONTROL PANEL

The MIMIC panel (figure 9-23, a foldout at the end of this chapter) contains a line diagram depicting the ship's electric plant configuration. Appropriate displays and controls are located

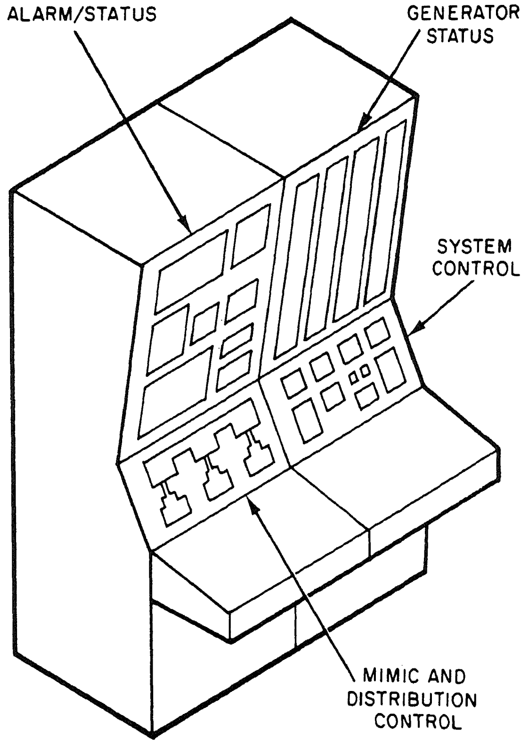

Figure 9-22.—EPCC—panel identification.

according to function. Split legend pushbutton switch/indicators combine the functions of starting circuit breaker (CB) close and trip commands and provide the corresponding status displays. Pertinent generator controls and indicators are also located on the MIMIC panel.

SYSTEM CONTROL PANEL

The system control panel (figure 9-24, a foldout at the end of this chapter) contains the controls and indicators for the voltages and frequencies of the three generators, governor and voltage regulator mode control and indicators, console mode control, SYNC (synchronizing) select, system frequencies and voltage control, self-test, power malfunction, and auto paralleling command switches/indicators.

GENERATOR STATUS PANEL

The generator status panel (figure 9-25, a foldout at the end of this chapter) continuously monitors alarm displays for each of the three generators and meters for various parameters of ship's power and shore power. The meters and displays are arranged in separate columns under the headings of power, current, frequency, and voltage for each generator and for shore power. This arrangement allows the operator to simultaneously monitor a particular output of all the power sources.

ALARM/STATUS PANEL

The alarm/status panel (figure 9-26, a foldout at the end of this chapter) contains the following displays and alarms: (1) demand displays, (2) generator and GT status and alarm indicators, (3) 400-Hz converter status and alarm displays, (4) main switchboard status displays, (5) emergency power status and alarm displays, (6) a battery voltage meter, (7) ground test controls, (8) switchboard and UPS indicators, (9) load shedding control and indicator, (10) synchroscope, (11) synchronizing lights, and (12) alarm acknowledge control.

OPERATIONAL CONTROLS

Electric plant remote manual and automatic operating control, metering, and configuration

status indicating components are located in the CCS at the EPCC. In normal operation the EPCC has complete remote control and monitoring capability of the electric plant. This capability includes the automatic, manual permissive, and manual CB control; automatic and manual generator set start and stop control; and voltage and frequency adjusting control.

A GTG control panel (LOCOP) (mounted on the side of each GTGS) provides the logic for start sequencing, normal stop sequencing, emergency engine shutdown, and other GTGS support functions. The main switchboards provide START and STOP pushbuttons for the GTGS and control and monitoring for the generators and CBs.

Details of operation of a GTGS from a switchboard and details of the distribution system are discussed in chapter 12. This chapter covers the operation of the electric plant from the EPCC where control of all three GTGSs is centralized.

GAS TURBINE GENERATOR SET MONITORING

Each GTGS has sensors that provide remote monitoring of the GTE and the generator. The sensor information is sent to the EPCC in three ways: directly from alarm contact switches, through alarm detector circuits in the generator control panel, or through S/CE No. 1.

Alarms

GTGS alarms at the EPCC include the following.

- Generator AIR TEMP HIGH (149°F)
- Generator FRONT/REAR BRG TEMP HIGH (195°F)
- Generator STATOR TEMP HIGH (165°F)
- Engine ENCL TEMP HIGH (200°F)
- Engine VIBRATION HIGH (3 mils)
- Turbine INLET TEMP HIGH (TIT) (1880°F)
- Gen/Reduction Gear LUBO PRESS LOW (7/20 psig)
- Engine/Reduction Gear LUBO TEMP HIGH (150°F)
- Engine/Reduction Gear LUBO STR ΔP HIGH (9 psid)
- Engine FUEL OIL STR ΔP HIGH (7 psid)
- Engine FIRE

Status Lights

Besides the alarm lights, the EPCC has four status lights for each GTGS.

- RUN—This indicator illuminates when the generator running relay at the switchboard is energized. The relay is energized when generator voltage is present at the generator power leads feeding the switchboard.

- CCS IN CONTROL—This indicator illuminates when the control selector switches at the switchboard and at the LOCOP are in the REMOTE position.

- AUTO STANDBY—This indicator is energized by the EPCC turbine start control logic when the following conditions are met.

1. HP air is available, or the generator run light is illuminated.
2. CCS IN CONTROL—(same as above).
3. The CB mode control selector switch at the switchboard is in the AUTO position. Also, the switchboard and generator control panel permissives are met.

    a. Governor control in NORMAL mode
    b. Voltage regulator control in NORMAL mode
    c. GB open (TRIPPED)
    d. GTG control panel in REMOTE

4. A generator-in-standby signal has been received from EPCC plant-status identification logic. This signal is generated when the plant configuration stored in a logic

memory is one of those for which that generator is in standby. For instance, a generator No. 3 in-standby signal is generated when configuration 1A, 1B, or 1C (figure 9-27) is stored in a logic memory.

5. Governor control is in the NORMAL mode.
6. Voltage regulator control is in the NORMAL mode.
7. Generator breaker is open.
8. The logic is not inhibited by an EPCC self-test.

- FAIL TO START—This indicator is no longer used.

ELECTRICAL DISTRIBUTION SYSTEM MONITORING

The generator status panel at the EPCC (figure 9-25) provides meter displays and alarms that monitor the output of the three GTGSs. An additional section of this panel is for monitoring shore power. Information for this panel originates at the main switchboards.

Meter Displays

Meter displays at the EPCC include

A-C Kilowatts	GTGS 1, 2, 3
A-C Amperes	GTGS 1, 2, 3, and Shore Power
Hertz (frequency)	GTGS 1, 2, 3, and Shore Power
A-C Volts	GTGS 1, 2, 3, Bus Tie and Switchboard

The voltage being displayed on the bus tie and switchboard panel meter depends on the position of the bus tie and switchboard voltage selector switch (EPCC system control panel, figure 9-24). The meter will display the individual signal designated by the selector switch.

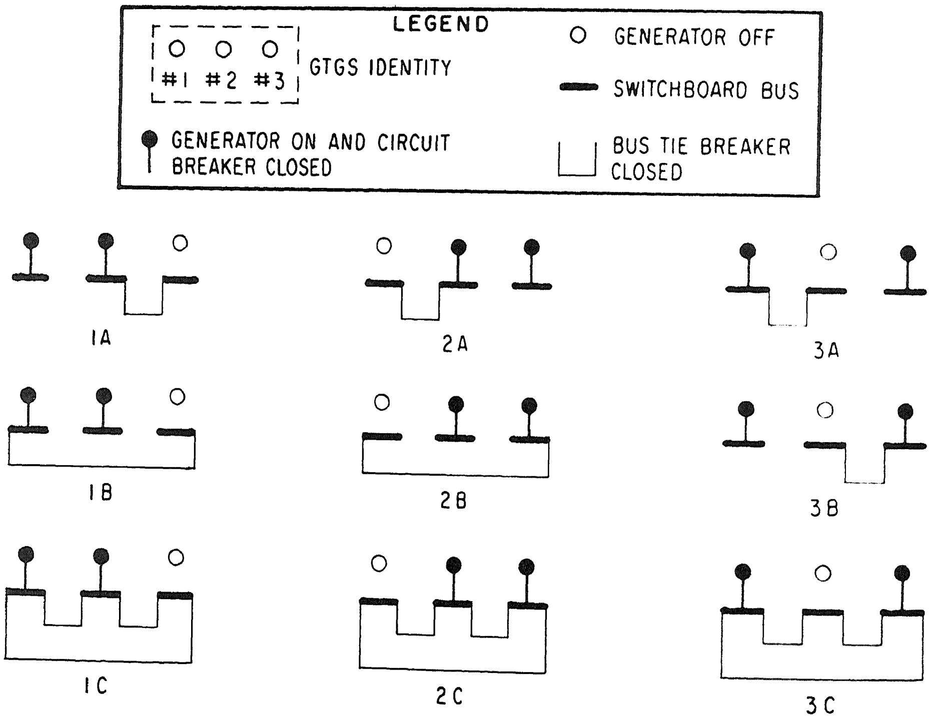

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Figure 9-27.—Standard electric plant configurations.

Alarms

Alarms provided at the EPCC generator status panel include

Generator	HIGH CURRENT	(3200 amp)
Generator	HIGH FREQUENCY	(62 Hz)
Generator	LOW FREQUENCY	(57 Hz)
Generator	HIGH VOLTAGE	(472 volts)
Generator	LOW VOLTAGE	(428 volts)
Shore Power	HIGH CURRENT	(2400 amp)

Shore Power

The shore power phase sequence meter (figure 9-25) receives signals from the shore power bus. When the phase sequence meter switch is on, all three white lights will illuminate. They remain illuminated as long as voltage signals are present for all three phases. The meter will indicate CORRECT PHASE SEQ if the phase rotation between the three inputs is in the correct sequence (ABC). Reverse phase rotation will cause the meter to indicate INCORRECT PHASE SEQ.

A SHORE POWER AVAILABLE indicator of the EPCC MIMIC panel illuminates when the EPCC has received a shore power available signal. The SHORE PWR AVAILABLE and BT 1S-2S ENERGIZED indicators are located on the MIMIC panel (figure 9-23) near the shore power CB pushbutton. Thus, the operator is aware of the status of the two buses before closing the shore power CB.

SWITCHBOARD GROUND DETECTOR

The EPCC alarm status panel has a main switchboard ground detector (figure 9-26). This assembly receives three-phase input and a ground input from ground test transformers at each main switchboard (when each of the switchboard control selectors is in REMOTE position). The EPCC selector switch will connect these inputs (switchboard No. 1, 2, or 3) to the primary side of the indicator light transformer. The three indicating lights will illuminate equally. When the GROUND TEST pushbutton switch is depressed, a ground test relay at the selected switchboard is energized. Then the common lead of the primary windings of the ground transformer on the switchboard is connected to ground. If a ground exists on one of the phases, the indicator for that phase light will go out (or glow dim). This is because the potential across the primary winding of the ground test transformer for that phase will be reduced or eliminated. The other two phase lights will brighten since the voltage across these phases is increased. Release of the GROUND TEST pushbutton switch will de-energize the ground test relay. The circuit will return to normal with all three lights illuminated equally.

SWITCHBOARD EMERGENCY POWER

An EMERGENCY PWR ON indicator light for each main switchboard is located on the EPCC alarm status panel (figure 9-26). Each light receives a signal from its respective switchboard when the switchboard is operating from its emergency power battery bank (24 volts d.c.).

CIRCUIT BREAKER CONTROL

The EPCC provides centralized control and monitoring of the three GBs, the six BTBs, the shore power breaker, and the five load center feeder breakers. The pushbutton indicators for these CBs are located on the EPCC MIMIC panel (figure 9-23). EPCC control of the CBs is established only when the GTG control selector switches at the switchboards are in the REMOTE position. Remote operation of CBs is performed by energizing 28-volt d.c. close and trip relays at the associated switchboard. When a close relay is energized, it completes a 110-volt a.c. circuit in the CB assembly. This energizes the breaker motor to start the closing sequence. When a trip relay is energized, it completes a 110-volt a.c. circuit in the CB assembly. This activates the trip coil and opens the breaker contacts. After the breaker opens, the motor will run to recharge the closing spring, arming the breaker for another closure.

The CB control at the EPCC can be divided into two categories: operator-initiated CB control and logic-initiated CB control. Operator-initiated

CB control is provided on the MIMIC panel through CB pushbutton switch/indicators. The indicators display the CLOSE or TRIP status of the CB during all modes of operation (except when certain sequences of the EPCC self-tests are in program). Control of the load center CBs is available in all modes of operation since no synchronization is required. The load center CBs connect the main switchboards to load centers for further distribution of electrical power. You can operate the CBs and BTBs from the EPCC during either the manual or manual permissive modes.

In the manual mode, the CB commands are sent directly from the EPCC to the open and close relays at the switchboard with no protective interlocking. In the manual permissive mode, CB trip commands are sent from the EPCC just like the manual mode. However, the close commands are not sent directly to the close relays at the switchboard. They are sent through the synchronizing monitor at the switchboard. The synchronizing monitor must be aligned to monitor the particular CB closed or no close command will be sent to the close relay. The synchronizing monitor is aligned by turning the SYNC select switch at the EPCC (when control is at the EPCC). When this switch is set to a particular CB, relays at the switchboard will be energized to align the synchronizing monitor to that CB. The synchronizing monitor will prevent a close command from energizing a close relay unless the difference in voltage between the on-line and oncoming units is less than 22 volts, the frequencies differ by 0.2 Hz or less, and the phase angle difference is between −30 and 0 electrical degrees. This prevents closing of a breaker in an out of synchronization condition.

The CB close commands originate in control logic when the EPCC is in the automatic operating mode. Breaker close commands can be issued as part of an automatic paralleling sequence or by the failure detection and recovery logic during an automatic configuration change. The BTBs 3S-1S and 3S-2S are the only breakers that will trip automatically. The auto trip commands isolate switchboard No. 3 if all three generators are in parallel for more than 2 minutes.

GAS TURBINE CONTROL

Control of the GT is available at the EPCC when the LOCOP and switchboard have been aligned for remote operation.

Start/Stop Control

Manual GTGS control available at the EPCC consists of a START pushbutton, a STOP pushbutton, and an HP AIR/LP AIR GTRB START MODE SELECTOR switch (figure 9-23). You can use the start controls only when the control transfer switches at the LOCOP and the switchboard generator control panel are in the REMOTE position. When a START pushbutton is depressed, a signal is sent to the HP AIR/LP AIR selector switch, which is spring-loaded, to the LP AIR position. A start signal is sent to the HP or LP start relay at the associated switchboard, depending on the position of the EPCC HP AIR/LP AIR selector switch. The energized switchboard relay will send a start signal to the GTG control panel. This begins either the HP air or LP air (as selected) start sequence. The GTGS is started and reaches running speed automatically. Before beginning the LP air start, you must align the starter air system for GTGS starting following the EOSS.

The EPCC STOP pushbutton switch (figure 9-23) is not affected by the control transfer switches. When the EPCC STOP pushbutton is depressed, a signal is sent to the turbine stop relay at the switchboard. This, in turn, sends a stop signal to the LOCOP to begin a normal stop sequence.

The EPCC is capable of automatically generating an HP air start command. It uses the same flow path as a manual HP air start command. The automatic HP air start command is a 1-second signal from the GT start control logic in the EPCC. The command is issued as part of the auto recovery sequence. This sequence is described later in this chapter. The EPCC logic cannot issue an LP start command; also, it cannot generate a signal to stop a GTGS.

Frequency Control

The frequency of each GTGS is controlled by an EG mounted in the associated GCU enclosure

located near the switchboard. The EG senses both the frequency of the PMA attached to the generator shaft and the load demand on the generator. The EG sends signals to a hydraulic actuator on the GT. The actuator adjusts the fuel flow in the engine to maintain engine speed. The EG system will regulate the frequency to a level set by a motor-driven reference potentiometer. When control is at the EPCC, individual frequency adjustment is made by activating this motor in the RAISE or LOWER direction. There are two modes of governor operation, NORMAL and DROOP. The NORMAL mode is isochronous, or constant frequency. The DROOP mode is an alternate mode where frequency decreases with increasing load. The DROOP mode is used for paralleling with shore power. Mode is determined by a latching relay in the associated GCU which can be controlled from the EPCC (when control is at the EPCC). You can find more information on the governor system in chapter 8.

Individual Governor Control

Individual FREQ adjust knobs (figure 9-24) are provided at the EPCC for each GTGS. These controls are disabled when the generators are in parallel, the VR. mode in NORMAL, and the GOV. mode is in NORMAL. When one of the FREQ adjust knobs is turned to the RAISE position, it energizes a relay in the associated switchboard. Then a command is sent to the EG to drive the d.c. motor in the raise direction. The motor will continue to run until the knob at the EPCC is released, or until the motor drive mechanism reaches its limit switch. The motor drives the reference potentiometer and will cause the governor to regulate at a higher frequency. A similar series of events occurs when a LOWER adjustment is made.

The NORMAL/DROOP pushbutton switch/indicator (figure 9-24) at the EPCC is used to select governor mode when control is at the EPCC. Depressing this pushbutton switch changes the state of the isochronous/droop latching relay at the governor. The lights of the indicator will illuminate to show either NORMAL or DROOP, depending on the state of the latching relay.

System Governor Control

When the voltage and governor controls are in NORMAL and the plant is in a parallel configuration, the system frequency control is activated for the parallel machines. The motor-driven frequency adjust potentiometer at each governor is automatically reset to a 60-Hz position. The governors are regulated to maintain equal load balance between the operating GTGSs. Frequency adjustments are then made with the system FREQ knob (figure 9-24) at the EPCC. Positioning this knob to the RAISE or LOWER position will energize the master frequency trimmer motor located in the EPCC. The motor drives a potentiometer which sends an equal trim signal to governors of the parallel machines. This will cause a change in the system frequency without affecting load balance between operating GTGs.

Automatic Paralleling Frequency Control

During automatic paralleling operation, the APD located in the CCS automatically adjusts the frequency of the oncoming GTGS to achieve synchronization. The EPCC must be in the automatic mode for automatic paralleling. All governors will be automatically set to 60 Hz before automatic paralleling begins. The APD adjusts the frequency of the oncoming unit by sending a raise or lower signal directly to the load sensing circuit of the governor. When automatic paralleling is achieved, the APD will remove the adjust signal. The governor will regulate to maintain frequency and load balance between the operating units.

GENERATOR CONTROL

Control of generator field excitation for a GTGS is maintained by its GCU. In the AUTO mode of operation, the GCU regulates the generator output voltage to a level set by a motor-driven reference potentiometer located at the regulator. In the MANUAL mode, excitation current from the GCU is set by a motor-driven rheostat located at the associated switchboard. When control is at the EPCC, voltage is adjusted by operating either the reference potentiometer motor (AUTO mode) or the manual rheostat motor (MANUAL mode) in the RAISE or LOWER direction. There are two modes of

reactive current compensation for the GCU: NORMAL and DROOP. Compensation mode is determined by a latching relay at the associated GCU. You can control the position of this relay from the EPCC (when control is at the EPCC).

Individual Voltage Control

The individual voltage controls (figure 9-24) at the EPCC are used to raise or lower generator voltage when a generator is operating independently. The individual voltage controls are disabled when the EPCC is operating the GTGSs in parallel with VR. and GOV. modes in NORMAL. These controls can function in either of two ways. If the AUTO voltage regulator mode has been selected, the RAISE or LOWER position on the voltage adjust knob will send 28 volts d.c. to the motor-driven regulator reference potentiometer at the GCU. The potientiometer will rotate it in the RAISE and LOWER direction. The voltage regulator will then control generator voltage at a new level. If the MANUAL voltage regulator mode has been selected, the RAISE or LOWER position on the voltage knob will send a 28-volt d.c. signal to the motor-driven manual voltage adjust rheostat at the switchboard. This changes excitation current being supplied to the generator field. The voltage regulator mode is set by a latching relay at the switchboard. You can change the state of this relay (automatic or manual) by depressing the AUTO/MANUAL pushbutton indicator (figure 9-24) at the EPCC (when the EPCC is in control).

System Voltage Control

System voltage control operates similarly to system frequency control. It is in effect only when the plant is in a parallel configuration with VR. and GOV. modes in NORMAL. You can turn the system VOLT adjust knob (figure 9-24) to the RAISE or LOWER position. This will cause the motor-driven reference potentiometer at each operating GTGS to turn equally in the RAISE or LOWER direction.

Automatic Paralleling Voltage Control

During automatic paralleling operations, the APD will automatically adjust the voltage of the oncoming unit to match the voltage of the on-line unit. The APD makes adjustments by sending raise or lower commands to the motor-driven reference potentiometer at the voltage regulator. It does this until the two GTGS voltages are matched. The voltage regulator reference is kept at this new setting after paralleling is achieved.

AUTOMATIC PARALLELING SYSTEM

The automatic paralleling system is used to automatically parallel an off-line GTGS with the energized main bus. Once activated, the system will adjust the generator voltage and engine speed of the oncoming GTGS with the on-line conditions, identify the proper time for CB closing, and then issue a close command to complete the paralleling operation. You can manually start the automatic paralleling sequence at the EPCC system control panel (figure 9-24). Under certain conditions it will be automatically started by the EPCC failure detection and recovery logic. The EPCC must be in the AUTO mode of operation for automatic paralleling operations. In the auto paralleling system, plant status identification and CB control are conducted by the EPCC logic; voltage and frequency monitoring and control are conducted by the APD.

An operator-initiated auto parallel sequence is started when one of three auto parallel pushbutton switch/indicators (GEN 1 & 2 PARALLEL, GEN 2 & 3 PARALLEL, or GEN 1 & 3 PARALLEL) is depressed. Both of the GTGs to be paralleled must be running or the operation will be aborted. The control logic evaluates the paralleling command based on the existing plant configuration. It does this by monitoring the open/closed status of the generator and BTBs. If paralleling cannot occur because of plant configuration, the sequence will be aborted. If the configuration is acceptable, the control logic will identify to the APD the on-line and oncoming units. The APD will then send raise or lower signals to the oncoming generator voltage regulator to match on-line voltage. It will also send raise or lower signals to the oncoming EG to match on-line frequency. When the frequencies and voltages are matched and the phase angles are within ± 15 electrical degrees for about 0.75 seconds, the APD will issue an in sync signal to the EPCC. The EPCC logic will start a GB close command and monitor for a breaker closed status. If the breaker closes within 3 seconds, the

sequence will be completed. The auto parallel indicator will illuminate to signal a satisfactory paralleling operation. The APD will remove voltage and frequency commands. The parallel generator will operate normally, sharing loads and currents. If the breaker does not close within 3 seconds, the GB TRIP indicator will flash. The sequence will abort.

A similar sequence is followed for automatic paralleling started by the failure detection and recovery logic. In a recovery sequence, the GTGS start commands are generated by the recovery logic before a paralleling command is sent to the auto parallel system. Plant status identification and CB control are provided by failure detection logic.

The automatic paralleling function is inhibited when shore power is being used. If all three generators are paralleled, the configuration logic in the EPCC begins a 2-minute time delay. If three generators are still in parallel after this interval, generator No. 3 and its switchboard will be isolated by automatic tripping of BTBs 3S-1S and 3S-2S (figure 9-23).

SYSTEM CONFIGURATION

The electrical system is designed so that two generators can supply all electrical loads. The third GTGS can be put on standby. Then it can automatically be started and synchronized to the bus if one or both of the on-line generators should fail. Automatic failure detection and recovery is available only when the EPCC is in control and in automatic mode. Also, the electric plant must be in a standard parallel or standard split plant configuration.

Standard Parallel Plant Configurations

In parallel plant operations, two generators are on line and paralleled. Also, all BTBs tie CBs are closed to connect the three main switchboards in a loop system. The possible combinations of two paralleled generators are designated 1C, 2C, and 3C as in figure 9-27. Configuration status logic at the EPCC identifies the on-line generators for auto recovery control.

Standard Split Plant Configurations

Standard split plant operation requires that two generators be on line, but not paralleled. The switchboard bus of the off-line generator is energized through the bus tie connection to one of the on-line generator switchboards. The remaining bus ties are not energized. The six possible standard split plant configurations are identified in figure 9-27 as 1A, 1B, 2A, 2B, 3A, and 3B. The configuration status logic at the EPCC can identify any of these configurations by monitoring the open and closed status of the generator and BTBs.

Nonstandard Plant Configurations

The open loop paralleled generator configurations (figure 9-28) energize all three switchboards

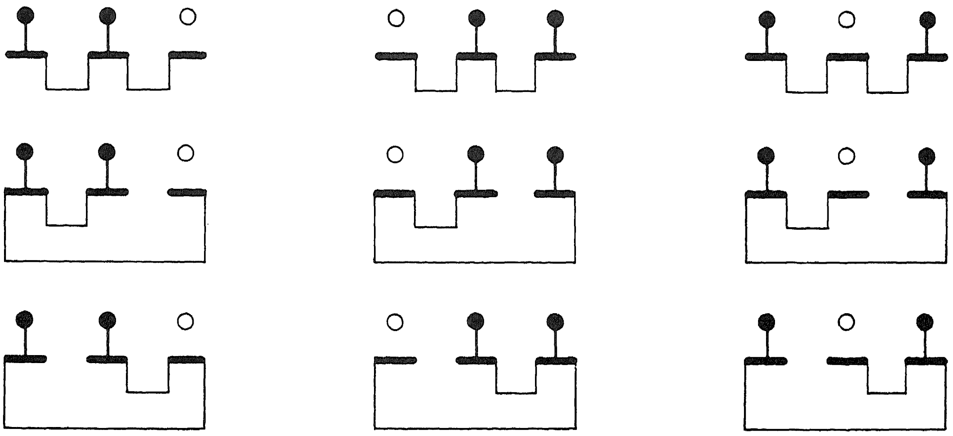

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Figure 9-28.—Nonstandard plant configurations.

with two generators. These configurations are operator selected, or they are the result of a failure. All electrical distribution functions are provided with these configurations, but automatic recovery capability is not available.

Emergency Configurations

Emergency configurations are shown in figure 9-29. Normal plant operation requires two generators in parallel or split plant configurations. In an emergency, with two generators inoperative, one generator must energize the three switchboards. Overpower protection will cause shedding of preselected nonvital and semivital loads. The generators have a 30-minute overload rating of 2200 kilowatts. If automatic load shedding does not reduce loading sufficiently, additional loads will have to be removed manually.

FAILURE DETECTION AND RECOVERY SYSTEM

The failure detection and recovery system is part of the EPCC control logic. It monitors the electric plant for a change in configuration or a failure of an operating GTGS. This control logic can identify a failure, evaluate plant configuration, and begin commands to restore the electric plant to a standard parallel operating configuration. In case the BTBs open while the system is in a standard parallel plant operating configuration, no attempt is made to change the new configuration.

A standard plant configuration is identified and stored in the EPCC logic memory whenever the CONFIG CHANGE RESET pushbutton is depressed. This standard configuration will remain in the memory, regardless of any subsequent change in configuration, until the CONFIG CHANGE RESET pushbutton (figure 9-23) is again depressed. The new standard configuration of that moment will then be stored in the logic memory. If the plant is not in a standard configuration at that moment, none of the nine memories will output a signal.

Automatic failure detection and recovery is available only when (1) the EPCC is in control and in the automatic mode, (2) the electric plant is in a standard plant configuration, and (3) one generator is in AUTO STBY. AUTO MODE ON is activated when the EPCC is in AUTO mode and the voltage regulator and governor are in NORMAL mode.

The response of the system to a particular failure is based on the type of failure and the plant configuration at the time of the failure. Plant configuration is monitored by the plant-status logic that uses contacts at each CB to determine breaker open/close status. A change of status of any BTB or GB constitutes a configuration change. GTGS failures are monitored by the GTGS monitoring circuits of the EPCC which transmit probable failure signals to the failure detection logic. When a failure occurs that leaves the plant in an unacceptable configuration, the recovery logic will try to restore the plant to an acceptable

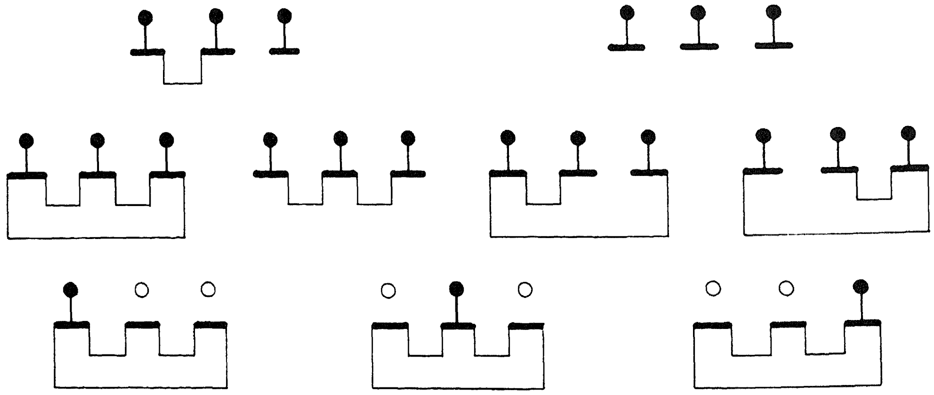

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Figure 9-29.—Emergency configurations.

configuration. This is done by closing BTBs or by starting and paralleling the standby GTGS.

Auto Recovery from Configuration C

Assume the system is in configuration C (figure 9-27) that has GTGSs No. 1 and No. 2 on line, all BTBs closed, and GTGS No. 3 in AUTO STANDBY. The failure detection and recovery logic monitors the plant configuration for change in

1. GB No. 1 closed status,
2. GB No. 2 closed status,
3. BTBs closed status,
4. Generator No. 1 probable failure, and
5. Generator No. 2 probable failure.

A generator probable failure will be started by any of the following GT or generator alarms.

- REAR BRG TEMP HIGH
- STATOR TEMP HIGH
- INLET TEMP HIGH
- ENCLOSURE TEMP HIGH
- AIR TEMP HIGH
- FRONT BRG TEMP HIGH
- LUBO PRESS LOW
- LUBO TEMP HIGH
- VIBRATION HIGH
- FIRE

Consider the case in which GB No. 2 opens. The following events take place.

1. The SYS CONFIG START alarm indicator illuminates flashing.

2. Generator No. 3 is given a start command and a 60-second timer is started. If the logic does not receive a generator No. 3 running signal before the 60 seconds has elapsed, an electric plant No. 3 malfunction signal is generated. Then the AUTO RCVY NOT AVAIL alarm indicator illuminates flashing.

3. The generator No. 3 running signal issues a command to parallel generators No. 1 and No. 3. At the same time, a 32-second timer will start. If the 32 seconds elapses before a generator in sync signal is received, an electric plant No. 3 malfunction signal is generated. Then the AUTO RCVY NOT AVAIL alarm indicator light illuminates flashing.

4. The generator in sync signal begins a close command to GB No. 3 and starts a 3-second timer. If GB No. 3 does not close within 3 seconds, a GB No. 3 failure to close signal causes the AUTO RCVY NOT AVAIL alarm indicator to illuminate flashing. Successful closing of GB No. 3 illuminates the SYS CONFIG CHNG COMPL status light and the AUTO RCVY NOT AVAIL light flashes.

Depressing the ALARM ACK pushbutton switch causes the flashing SYS CONFIG CHNG START and AUTO RCVY NOT AVAIL lights to illuminate steadily.

Depressing the CONFIG CHANGE RESET pushbutton switch resets the logic memory to the new plant configuration. The logic memory identifies the new configuration as 3C. The SYS CONFIG CHNG START and SYS CONFIG CHNG COMPL lights extinguish. The AUTO RCVY NOT AVAIL light also extinguishes if generator No. 2 meets all the requirements of being in auto standby.

If instead, both GBs No. 1 and No. 2 remain closed and there is a generator No. 2 probable failure, the logic commands generator No. 3 to start. It does not issue a command to parallel with the on-line generators. Operator action is required to either correct the generator No. 2 probable failure or replace it with generator No. 3.

If both CBs remain closed and there is no generator probable failure, the logic checks to see if any BTBs have opened. If any BTBs have opened, the SYS CONFIG CHNG START light illuminates flashing. The first BTB to open stores a signal in a logic memory. This causes the SYS CONFIG CHNG COMPL light to illuminate.

Depressing the CONFIG CHANGE RESET pushbutton switch resets the logic memory to the new plant configuration. It will identify the new configuration as being neither 1A, 1B, nor 1C.

This eliminates a generator No. 3 in standby signal. Therefore, the generator No. 3 AUTO STBY light extinguishes. The AUTO RCVY NOT AVAIL light illuminates steadily.

Auto Recovery from Configuration A

Assume that the plant is in the 1A configuration (figure 9-27) where generators No. 1 and No. 2 are on line and only BTB 2-3 is closed. The failure detection system monitors the plant configuration for change in

- GB No. 1 closed status,
- GB No. 2 closed status,
- Generator No. 1 probable failure,
- Generator No. 2 probable failure, and
- BTB 2-3 tripped status.

If GB No. 2 opens, the following events take place.

1. A command is issued to close all BTBs.
2. The SYS CONFIG CHNG START light illuminates flashing.
3. Generator No. 3 is given a start command and a 60-second timer is started. If the logic does not receive a generator No. 3 running signal before the 60 seconds has elapsed, an electric plant No. 3 malfunction signal is generated. The AUTO RCVY NOT AVAIL light illuminates flashing.
4. The generator No. 3 running signal issues a command to parallel generators No. 1 and No. 3. At the same time, a 32-second timer starts. If the 32 seconds elapses before a generator in sync signal is received, an electric plant No. 3 malfunction signal is generated. The AUTO RCVY NOT AVAIL light illuminates flashing.
5. The generator in sync signal begins a close command to GB No. 3 and starts a 3-second timer. If GB No. 3 does not close within 3 seconds, a GB No. 3 failure to close signal causes the AUTO RCVY NOT AVAIL light to illuminate flashing. Successful closing of GB No. 3 illuminates the SYS CONFIG CHNG COMPL light. The AUTO RCVY NOT AVAIL light illuminates flashing.

Depressing the ALARM ACK pushbutton switch causes the flashing SYS CONFIG CHNG START and AUTO RCVY NOT AVAIL lights to illuminate steadily.

Depressing the CONFIG CHANGE RESET pushbutton resets the logic memory to the new plant configuration. The logic memory identifies the new configuration as 3B. Then the SYS CONFIG CHNG START and SYS CONFIG CHNG COMPL lights extinguish. The AUTO RCVY NOT AVAIL light also extinguishes if generator No. 2 meets all the requirements of being in auto standby.

Consider the case in which GBs No. 1 and No. 2 remain closed in the 1A configuration and there is no generator probable failure. The EPCC logic in this case checks to see if BTB 2-3 is open. If BTB 2-3 has opened, the SYS CONFIG CHNG START light will illuminate flashing. A command will be issued to close BTB 1-3 and BTB 3-1. Closing of these breakers causes the SYS CONFIG CHNG COMPL light to illuminate. The AUTO RCVY NOT AVAIL light will still be illuminated since BTB 3S-2S is still closed. Opening this breaker will cause this light to extinguish, and generator No. 3 will then be in AUTO STANDBY with AUTO RECOVERY available.

LOAD SHEDDING SYSTEM

Manual initiation of load shedding is accomplished from the alarm status panel of the EPCC by depressing the pushbutton switch/indicator LOAD SHED ACTIVATED. This switch transfers 28-volt d.c. power to a load shedding control relay in switchboard 2S. The LOAD SHEDDING ACTIVATED indicator on the pushbutton switch at the EPCC illuminates.

Automatic load shedding is started by any overpower sensor circuit (one in each switchboard) energizing a self-contained relay whose contacts are in parallel with the EPCC pushbutton switch/indicator LOAD SHED ACTIVATED. Closure of these contacts energizes the same load shedding control relay in switchboard 2S. The LOAD SHEDDING ACTIVATED indicator on the pushbutton switch on the EPCC illuminates.

When the load shedding control relay is energized, its contacts pick up tripping relays in each main switchboard. The tripping relays complete power circuits to the trip coils on selected main switchboard CBs. The coils open the CBs to remove load from the line. Additionally, other loads are similarly inhibited in load center switchboards by activation of tripping relays by their load shedding control relays.

The tripping relay also provides power to a time delay relay in each main switchboard. The time delay is 5 seconds. If either the EPCC LOAD SHED ACTIVATED pushbutton switch/indicator or the overpower sensor is activated for 5 seconds, the time delay relay is picked up. The contacts of this relay pick up additional equipment CB trip coils and, consequently, further reduce load.

Use of the EPCC LOAD SHED ACTIVATED pushbutton switch/indicator or overpower sensor detection of overloads is referred to as first stage load shedding. After 5 seconds of either of these activations, second stage load shedding is entered.

UNINTERRUPTIBLE POWER SYSTEM

The EPCC alarm/status panel (figure 9-26) provides monitoring for the emergency power source, referred to as the UPS. Four alarm indicators are on the panel associated with the UPS system.

1. MAIN ENGINE ROOM NO. 1—Indicates control equipment in that space is operating on UPS.

2. MAIN ENGINE ROOM NO. 2—Indicates control equipment in that space is operating on UPS.

3. BATTERY CHARGING—Indicates current is being supplied to the UPS battery bank by the UPS battery charger.

4. BATTERY LOW VOLTS—Indicates voltage at the battery bank is low (about 120 volts).

THE 60/400-HERTZ POWER SYSTEM

The three 60/400-Hz, three-phase converter units each provide a shutdown signal, a summary temperature high signal, and a power available signal to the EPCC alarm status panel (figure 9-26). All signals are activated from relays in the 400-Hz power distribution switchboards. The SHUTDOWN warning indicating light is illuminated when the power available relay is de-energized. The SMY TEMP HIGH warning indicating light is illuminated when either the high temperature or the cooling failure relay is energized. The POWER AVAILABLE illuminates when the power available relay is energized.

PROPULSION AND AUXILIARY MACHINERY INFORMATION SYSTEM EQUIPMENT (PAMISE)

The PAMISE has the following components.

- Central Information System Equipment (CISE)

- Signal Conditioning Enclosures (S/CEs) 2 and 3 (located in the MERs)

The PAMISE is used to monitor the propulsion plant, electric plant, and selected ship's auxiliaries. It also provides printed bell and data logs and operator data.

CISE MONITORING

The CISE is located in the CCS. The components that make up the CISE include the executive control unit (ECU), S/CE No. 1, two printers, and the associated power supplies. The ECU is the main component of the system. It is a special purpose computer used to collect, analyze, and distribute data for use by the operators of the engineering plant. The ECU gathers data from the ship's equipment by collecting inputs from the S/CEs, PAMCE, and EPCC. Data is outputted to the operators in the form of alarms, status indicators, printed logs, and digital displays. No propulsion plant control is accomplished in the ECU.

The ECU has a monitor and control panel (figure 9-30) that allows operator logging requests, demand display information, and date/time information. This panel is mounted on the front of the ECU. Another control panel, the ECU test panel, (figure 9-31) (located on the rear of the ECU) is used by maintenance personnel when performing maintenance on the computer.

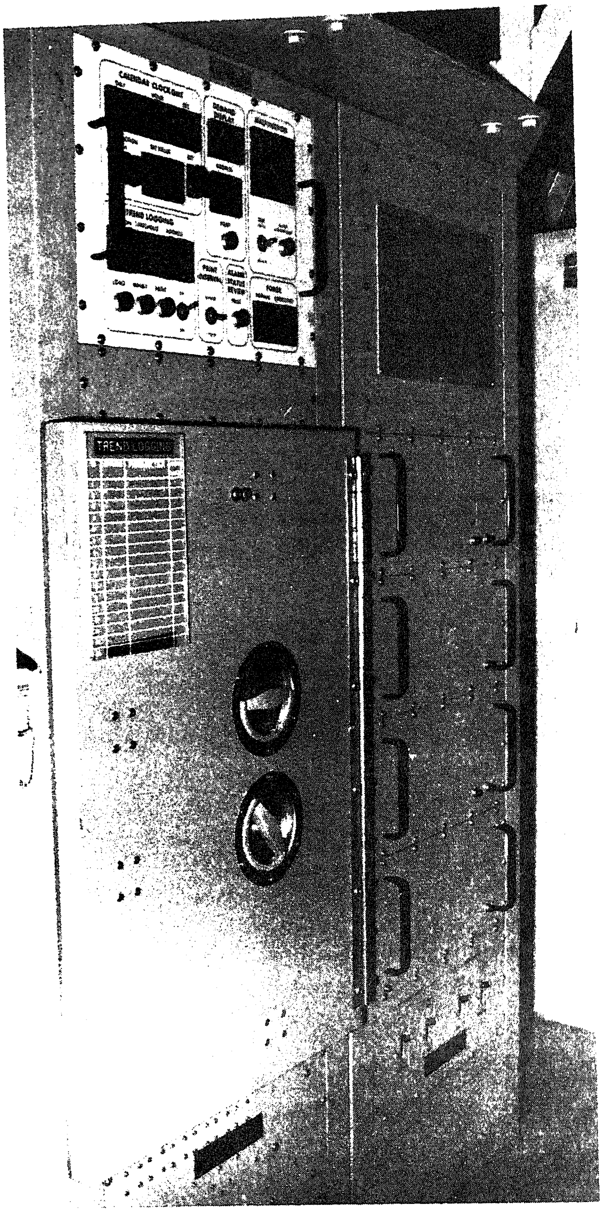

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Figure 9-30.—ECU monitor and control panel.

Monitor and Control Panel

The monitor and control panel of the DD-963 CISE (figure 9-30) is divided into seven sections.

- Calendar/GMT clock
- Demand display
- Malfunction
- Trend logging
- Print interval
- Alarm status review
- Power

CALENDAR/GMT CLOCK.—This section contains a Julian calendar display and a Greenwich mean time digital clock. Julian dates are numerically sequential days of the year. For example, January first is day 001; January second is day 002; December thirty-first is day 365 (except in a leap year when it is day 366). A GMT clock allows logging to be consistent from time zone to time zone without having to note time changes. (NOTE: Ship's policy may dictate logging in local time, and the clock may be set to any time zone.)

Controls are available for setting the clock and calendar. You will find instructions for setting these in your ship's EOP.

DEMAND DISPLAY.—A DDI is located on the monitor. This display allows operators to display a selected parameter by setting up the address on the thumbwheels. Like all other DDIs, you can select and display any plant parameter if it has a DDI address.

A PRINT pushbutton is also associated with the DDI on the CISE. Depressing this pushbutton causes the parameter selected by the address to be printed on the data log. The DDI index also has special addresses that allow group printouts to be printed on the data log. Printouts of groups include areas such as power train, fuel oil, lube

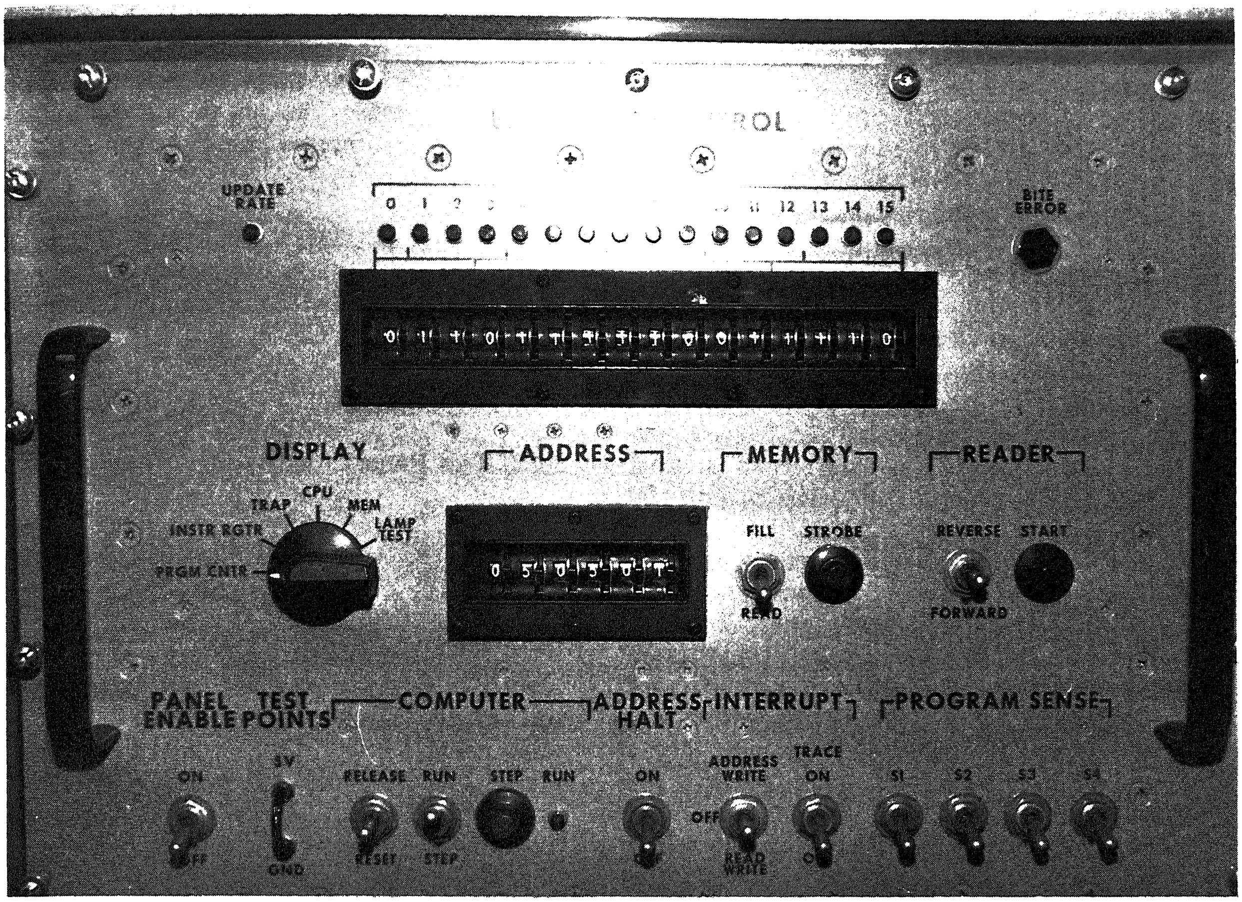

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Figure 9-31.—ECU test panel.

oil, GTM, GTG, and 60-Hz distribution. Consult your DDI index for the addresses of these printouts.

MALFUNCTION SECTION.—The malfunction section has ten indicators, an acknowledge pushbutton, and an alarm/status test switch. These alarms alert the operator when malfunctions occur within the PAMISE system. The ten malfunction alarms include

- ICC-S/CE 1
- S/CE No. 2
- Power Supply
- Bell Logger
- Bell Logger Paper Low
- ICC No. 2
- S/CE No. 3
- Clock Not Set
- Data Logger
- Data Logger Paper Low

When a malfunction occurs in one of these areas, the alarm will flash and a buzzer will sound. Depressing the ALARM ACKNOWLEDGE pushbutton will silence the buzzer and cause the indicator to come on steady. The alarm indicator will extinguish when the malfunction is cleared.

TREND LOGGING.—The trend logging feature of the CISE allows certain parameters to be printed onto the data log when a selected limit is exceeded. The trend logging section has three groups of thumbwheels, three pushbuttons, and an on/off switch. The three thumbwheel groups are labeled FUNCTION, THRESHOLD, and ADDRESS. The function thumbwheel picks 1 of 16 trend logging memory locations. The threshold allows you to preset the amount of variance of the parameter before printout occurs. This range is set between 1 to 10 percent of full scale. The address section is used to select the parameter to be trend logged.

The three pushbuttons labeled LOAD, INHIBIT, and PRINT are used when setting, securing, and reviewing the trend logging. By turning the trend logging on with the toggle switch, you program the trend logging functions with these pushbuttons and the thumbwheels. To use trend logging, you must program it. You may use any or all of the 16 functions. To program a parameter, first, you select a function not being used on the function thumbwheel. Next, you set in the alarm threshold. For instance, if you are logging a parameter whose range is 0 to 200 psi, for every 2-psi change a 1-percent threshold prints out. For every 20-psi change a 10-percent threshold prints out. Third, you must set in the address of the parameter to be logged. After setting all the thumbwheels, you depress the LOAD pushbutton to program the selected parameter into trend logging.

The INHIBIT pushbutton is used to stop logging one of the functions. To stop a function, you select the function on the thumbwheel and depress the INHIBIT pushbutton. If you depress the PRINT pushbutton, the data logger prints out all active functions. This allows you to observe all parameters being monitored.

Normally, trend logging is not used all the time. It is useful for monitoring recently repaired equipment, such as a new bearing, to establish trend data. It is also useful for logging data during full power and economy trials.

PRINT INTERVAL SWITCH.—The PRINT INTERVAL switch sets the interval when the data logger will print a complete plant printout. You may set it for 1 hour or 4 hours depending on ship's instructions.

ALARM STATUS REVIEW.—The ALARM STATUS REVIEW pushbutton commands the data logger to print out all active alarms in the ECSS. This function is useful for the EOOW to review the active alarms and out-of-limits parameters before relieving the watch.

POWER SECTION.—The power indicators allow you to monitor the status of the power supplies in the PAMISE system. They indicate whether CISE, S/CE 2, and S/CE 3 are on normal SS power or on UPS.

ECU Test Panel

The ECU test panel (figure 9-31) is located inside the CISE enclosure at the back of the CISE cabinet. The test panel is the primary interface to the ECU. Through this panel (operated only by experienced GSEs) the computer program is loaded, run, and maintained. Specific instructions on the use of this panel are found in the PAMISE technical manuals. The potential for causing malfunctions to the entire ECSS network by operation of this panel by inexperienced maintenance personnel is very high. You must have a thorough understanding of the serial data networks, binary logic, and digital equipment before operating functions of the ECU test panel.

ECU Operation and Programs

The ECU of the PAMISE is a general purpose stored-program digital computer. It accepts data representing operating values and status of the ships' propulsion, electrical, and auxiliary machinery. The data is processed, scaled to engineering units, and sent, if required, to the digital display or the bell and status/alarm loggers. The sensory information leaving the S/CEs is on a scale of 0 to 1000. If the engineering units are on a scale of 0 to 600, the computer must recognize that it has to multiply, or scale, this input from the S/CE by a conversion factor of 0.6. The computer does these tasks under direction of its stored program called the ECU program. This program is entered into the

computer memory by a tape reader. The program has seven major functions or subprograms.

- Executive
- Bell Logging
- Alarm Logging
- Change of Status Logging
- Trend Logging
- Data Logging
- Self-Test

Each subprogram can be requested in a variety of ways. When a subprogram is called up and working, it is called a task. A task has smaller jobs or pieces of work called routines. This discussion will be limited to the task level description for program analysis.

EXECUTIVE SUBPROGRAM.—The executive subprogram directs and organizes the activities of the computer. The following tasks are performed.

1. Responds to hardware interrupts. A hardware interrupt is performed when an output or input device tells the ECU it needs information or it is ready to give the ECU information. An example of this is when the matrix printer is performing a data log. The ECU provides the printer with only a small portion of the total log (one line); hence, the printer must tell the ECU (interrupt) when it is ready for more information.
2. Schedules tasks to be performed in priority order. This order is

    a. Bell Logging
    b. Alarm Logging
    c. Change of Status Logging
    d. Trend Logging
    e. Data Logging
    f. Self-Test

The program is written so that if a data log is being performed and a bell log (higher priority) is requested at the next interrupt in the data log, the bell log will be picked up and performed. The data log will be shelved for the duration of the bell log, and then resumed.

3. Inputs parameter data and status.
4. Services the demand displays.
5. Begins the start and restart of all routines (a set of routines makes up a subprogram).
6. Handles operator requests for various types of logging.
7. Outputs self-test status words.

BELL LOGGING SUBPROGRAM.—The bell logging subprogram has the responsibility for performing the following tasks.

1. Each second the status of the five parameters below are checked to determine if one or more of them have changed. If a change is found, an output of one print line is formed. It gives the date and time and the current status of the following five parameters.

    - Station in control of port shaft
    - Station in control of starboard shaft
    - Ordered plant mode
    - Port shaft throttle mode
    - Starboard shaft throttle mode

2. When an order or acknowledgement of the standard order EOT occurs for either port and/or starboard shafts, an output of two print lines is formed. The first line has the date and time, the port order and/or acknowledgement, and the actual values of port shaft rpm and propeller pitch. The second line has the starboard order and/or acknowledgement and the actual values of starboard shaft rpm and propeller pitch.
3. Each second the rpm and pitch settings from the EOT (digitized) for both shafts are checked for changes greater than specified limits. If a limit is exceeded for a predetermined length of time, two print lines are formed. The first print line has the date and time, the port rpm and/or pitch settings that changed, and the actual values of port rpm and pitch. The second line has the starboard rpm and/or pitch settings that changed

and the actual values of starboard rpm and pitch. These stored limits for an EOT change are

RPM change	±5 rpm
RPM time delay	5 seconds
Pitch change	±5 percent
Pitch time delay	5 seconds

4. Each second the actual rpm and pitch for both shafts are checked for changes greater than the stored limits. If such a change is found, two print lines are formed. The first line has the date and time and the value(s) of port rpm and/or pitch that changed. The second line has the value(s) of starboard rpm and/or pitch that changed. These stored limits for an actual rpm or pitch change are

RPM change	±5 rpm
RPM time delay	15 seconds
Pitch change	±5 percent
Pitch time delay	15 seconds

ALARM LOGGING SUBPROGRAM.—The alarm logging subprogram can perform one of two tasks listed below.

1. Each second the alarm status of each parameter is compared with the alarm status of that parameter from the previous 1-second check. For each change found (there may be more than one), a print line is formed with date and time, parameter that went into or out of alarm, parameter's value (if analog input), condition of parameter (high/low), and is prefixed with title of log (alarm) and if parameter went out of alarm (reset).

2. On operator demand, a search is made for each parameter that is presently in an alarm state. A print line is formed for each parameter in alarm with information similar to that given above (1) but is prefixed with the title of Alarm Review. This is known as an Alarm Status Review.

CHANGE OF STATUS SUBPROGRAM.—A change of status subprogram monitors the state (on/off, open/close) of those parameters selected by the subprogram. If a change is detected, a print line is formed (one line per parameter). It has date and time, parameter, state or condition of that parameter, and is prefixed with the title of Status Changed.

TREND LOGGING SUBPROGRAM.—The trend logging subprogram has 16 tasks. Each can monitor an operator-selected parameter (one parameter per task). This provides a one-line printout if a parameter exceeds an operator-selected threshold value (1 to 10 percent of that parameter's span; note, zero on the thumbwheel is 10 percent). The program can have any of the 16 parameters or tasks inhibited at operator discretion. The subprogram forms an output line with date and time, parameter, value, and is prefixed with the title Trend. The operator can request a listing of all functions (up to the 16) to be entered into the trend logging subprogram. In this listing, each line contains the information listed above with the exception that a function listing number (1 through 16) is included and the title is changed to Trend Review.

DATA LOGGING SUBPROGRAM.—The data logging subprogram provides for four types of data output or tasks as follows.

1. The data log normal task is started at either 1-hour or 4-hour intervals (operator-selected) on the hour. The log has a printout of all parameters and status inputs and is prefixed with the title Data Log.

2. The data log demand task is started by the operator by activating the PRINT pushbutton at either the PACC or CISE with a DDI number of 800 entered at the respective DDI. The output is similar to that of a data log normal task except that it is prefixed with the title Demand Log.

3. The data log group task is started by the operator by activating the PRINT pushbutton at either the PACC or CISE with a specific DDI number between 801 and 899 entered at the respective DDI. The output is prefixed with the title Demand Group Log. Specific 800 series DDI

numbers that produce equipment group printouts are

Gas Turbine Module

1A = 801

1B = 802

2A = 803

2B = 804

Gas Turbine Generator Sets

#1 = 811

#2 = 812

#3 = 813

60-Hertz Power Distribution

Switchboard 1S	= 821
Switchboard 2S	= 822
Switchboard 3S	= 823
Bus Tie	= 847
Fuel Oil (service)	= 851
Lube Oil	= 861
Power Train	= 841

4. The data log single entry task is started by the operator activating the PRINT pushbutton at either the PACC or CISE with a DDI number for the parameter wanted entered at the respective DDI. The printed output in this task is not prefixed with a title for this log.

SELF-TEST SUBPROGRAM.—The self-test subprogram performs the following six tasks.

1. Sums the contents of all the memory locations that are fixed and not modified by the program. This summation is compared with a reference sum.

2. Writes a predetermined set of test words into a memory location, reads it back out, and then compares the readout with the word as it was written in. Each location is exercised by this set of test words or patterns before proceeding to the next location. This test is done only to those portions of the memory that can be program modified.

3. Computes the alarm status of each parameter and compares it with the alarm status given from the S/CEs.

4. Uses the test bit information from each A/D converter in each S/CE and the data representing the parameter value to analyze possible hardware faults.

5. Checks reference voltages used by various portions of the PAMISE.

6. Analyzes the results of the above tests to determine and indicate in which enclosure the failure occurred and what printed circuit card in that enclosure failed.

SIGNAL CONDITIONERS

Signal conditioning is done by the PAMISE at the S/CEs No. 1, No. 2, and No. 3. The purpose of these S/CEs is to convert all the sensory inputs into a common electrical range of 0 to 10 volts d.c. This is done to make them compatible with the rest of the ECSS. S/CE No. 1 monitors the electric plant and auxiliary parameters; S/CEs No. 2 and No. 3 monitor the main propulsion parameters. Six basic types of signal conditioning done are

1. voltage signal conditioning,
2. current signal conditioning,
3. RTE signal conditioning,
4. tachometer/frequency signal conditioning, and
5. wattmeter signal conditioning.

Each of the above conditioners receives a sensor or external signal conditioner voltage, current, ohmic, or frequency, respectively. These inputs are converted to a 0- to 10-volt d.c. analog signal. These signal-conditioned parameters are processed by other electronic circuitry of the ECSS for alarm generation, analog meter displays, and digital demand displays. The other electronic circuitry by which this 0- to 10-volt d.c.

signal is processed and paths by which the information flows will be discussed with each topic. Discrete contact sensor signals are allowed to pass through the signal conditioners unaffected.

INTERCONSOLE HARDWIRE COMMUNICATION

A limited number of control and indicator signals of the ECSS consoles are communicated between consoles by hardwire or direct link. A summary of these controls and indicators follows.

1. Emergency control at the PACC to the PLCC
2. Throttle/pitch controls at the SCC to the PACC and the PACC to the PLCC
3. Clutch/brake manual control at the PACC to the PLCC
4. Service tank valve control at the PACC to the PLCC
5. Bleed air control at the PACC to the PLCC
6. Analog meter signals from the S/CE to consoles
7. Most indicator lights from the S/CE to the PLCC

SERIAL AND PARALLEL DATA COMMUNICATION

Most of the control and status information communicated between the ECSS control consoles is exchanged in the form of binary signals (these are discrete one of two state signals, characterized by voltage levels and indicating conditions such as on/off). These signals are in groups or arrays of information known as data words. Each binary signal within the data word is called a data bit. It has a binary zero or a binary one logic value. The number of data bits in a data word is referred to as the word bit length. The data words can be exchanged in parallel or serial format.

Parallel Format

In this format, the data transmitting and receiving electronics hardware must have one data line (wire) for each data bit. For example, a 10-bit data word requires 10 data lines. In parallel data word transmission and reception, each bit of the data word is presented at the same time on the data lines. Therefore, the entire data word is sent or received at the same time. Parallel format is used only for data communication within a console to allow more rapid communications and transfer of information. It is also used to minimize the electronic hardware required.

Serial Format

In serial format, data bits are sent and received one at a time. This is done in a timed sequential manner using a single data line. Serial format is used for data communication within a console and between consoles. The data line between consoles is time shared. Clock synchronization between consoles permits information exchange control. Two major types of data lines for serial data transmission are the command and control serial data system and the demand display serial data system. The advantage of serial data format is the substantial reduction of the amount of wiring required for communications.

The command and control serial data system (figure 9-32) is an electrical loop system with a synchronizing bus, clock bus, and data bus. This data bus carries information about plant status/alarms, EOT commands, and plant equipment commands. Figure 9-32 shows what type of information originates from each console (except the CISE which only receives information off this data bus) and is placed on the serial data bus. For example, the PACC originates the following types of information.

- Auto/manual GTM commands
- EOT acknowledgement

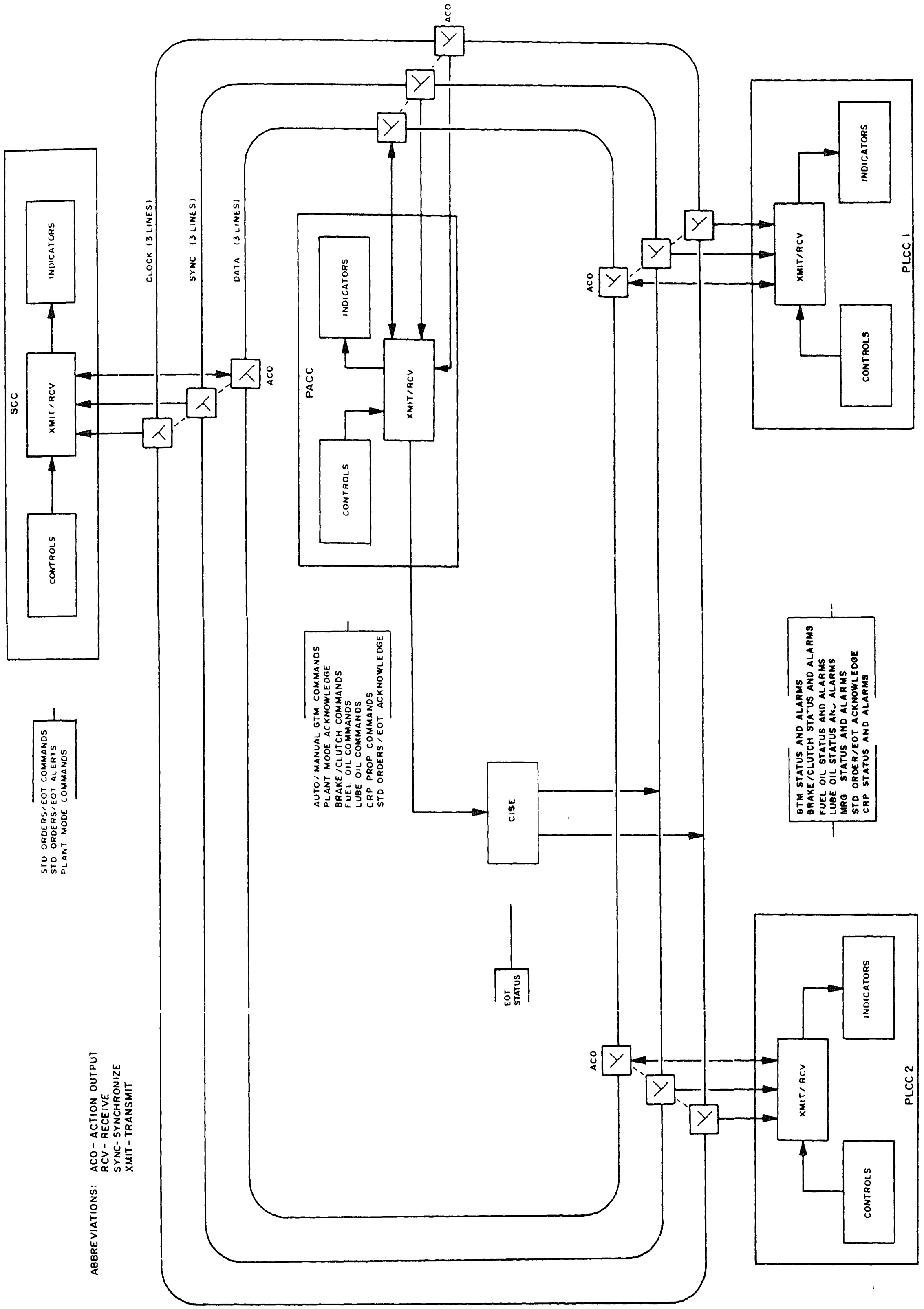

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Figure 9-32.—Command and control serial data network.

- Brake/clutch commands
- Fuel oil commands
- Lube oil commands
- CRP propeller commands

The EOT acknowledge signals from the PACC are received by all consoles and CISE. The equipment commands, however, are received by that particular PLCC controlling that equipment. An example of this would be the fast-slow-stop signals of the fuel oil service pump generated by the PACC operator.

NOTE: The serial data bus has equipment status and alarm information that originates from the PLCCs. Most of the alarm information, in turn, comes from the S/CE associated with that PLCC; most of the status information comes from the plant equipment. It is important to recognize that the S/CEs do NOT directly send information onto the command and control data bus.

The CISE receives plant equipment status and EOT order/acknowledgements off this serial data bus for logging purposes. An example of equipment status information is lube oil pump A fast. NOTE: The CISE does *not* send data information onto the command and control data bus.

This serial data system is a time-shared bidirectional information bus network used to exchange command and control data between the ECSS consoles of the PACC, PLCC No. 1, PLCC No. 2, SCC, and the CISE. Each of the three buses has three separate lines or conductors. That is, the data bus has three lines, as does the clock sync buses. Each of these three lines carries the identical binary information data simultaneously; but, they are associated with three separate cable runs routed through different geographic areas of the ship: port side, center, and starboard side. The triple redundant lines serve to increase and maintain system communication reliability if a cable casualty occurs. Two cables, however, are required for system operation.

The command and control data listed alongside each console in figure 9-32 is exchanged in the form of 16-bit serial data words. Twelve bits of each word are used to convey control information. The remaining four bits are used for parity indication and time spacing between serial data words. Each serial data word has a word period length of 1.95 milliseconds. Each control console of the ECSS sends command and control data onto or receives command and control data off of the serial data loop during certain fixed time periods within each second of system operation. Exceptions to this are that (1) PAMISE and the EPCC do not send data on the command and control data bus, and (2) the EPCC does not receive information off the command and control data bus.

One second of system operation is divided into four 250-millisecond word blocks. Each word block is further divided into 128 individual word periods. One word period is therefore, as mentioned earlier, 1.95 milliseconds in length. A maximum of 512 serial data words per second can be exchanged over the command and control serial data bus between the consoles of the ECSS. This network is shown in figure 9-32. Figure 9-33 shows the relationship of word periods and word blocks to 1 second of system operation.

The serial data loop is a time-shared system wherein only one console at a specific time can transmit onto the data bus. However, more than one console, including the transmitting console, can be receiving the same transmitted data at the same time. Serial data logic circuitry within each console is used with the system clock located in the PAMISE. This system clock controls the timing of the console sending and receiving circuits.

As shown in figure 9-32, the PACC, PLCC No. 1, PLCC No. 2, and the SCC are each connected to the sync, clock, and data buses and hence interconnected to each other. This connection is done through an action cutout (ACO) switch assembly associated with each console. Each ACO is connected to two adjacent ACO switches. The order of connection is unique. For

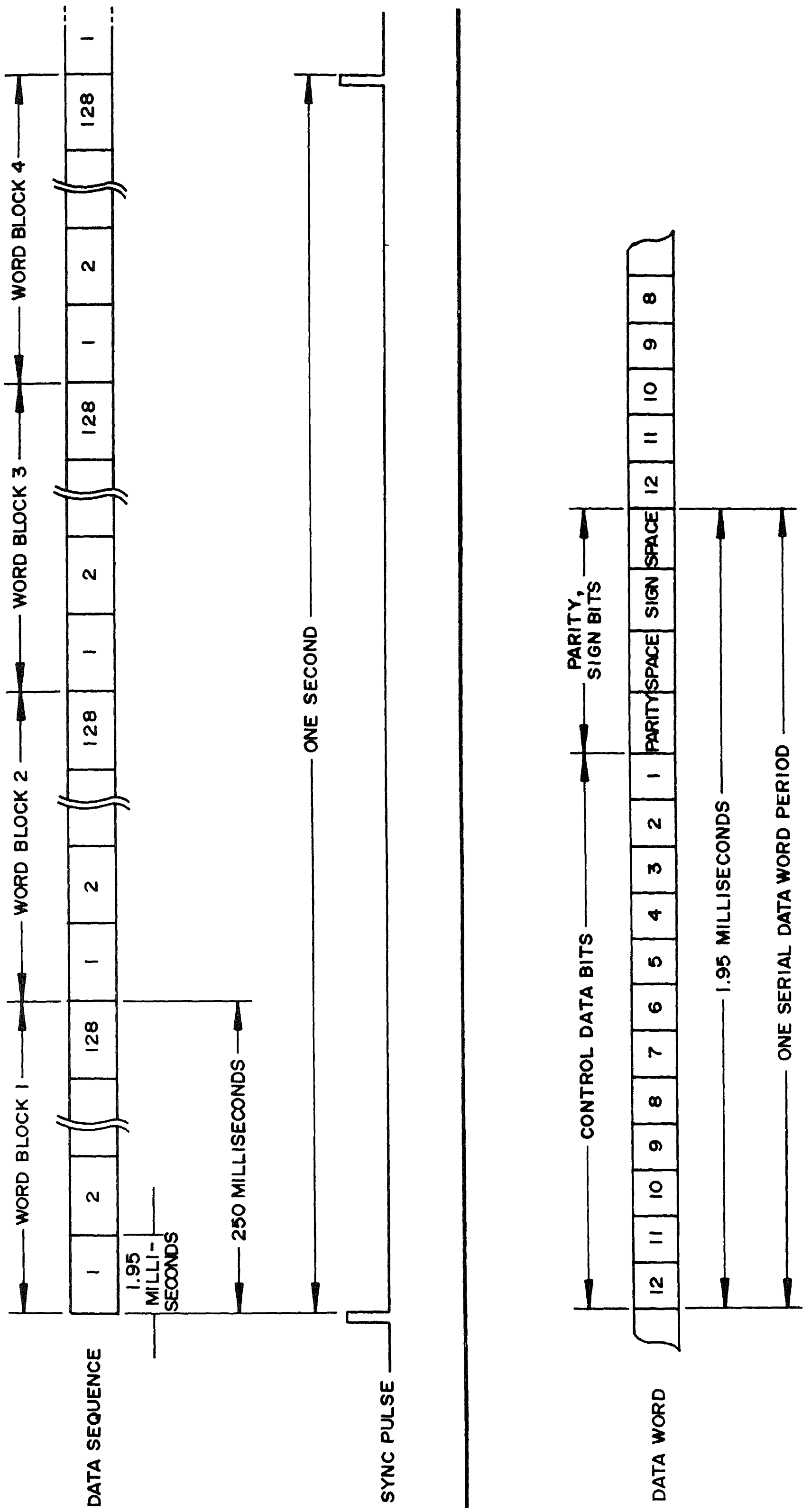

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Figure 9-33.—Serial data word blocks and word periods.

example, the SCC ACO connects to the PACC ACO and PLCC NO. 2 ACO; the PACC ACO connects to both the SCC ACO and to the PLCC NO. 1 ACO, and so forth. Thus, each console has two alternate communication paths with the other units on the serial bus loops. The ACO switch has the following four different functional positions.

1. Normal—Console connected through ACO switch to both adjacent consoles.

2. Adjacent Disconnect—Console disconnected from adjacent console on loop. Two positions are on the switch, one for each adjacent console.

3. Electrical Disconnect—Console disconnected from loop, but loop continuity is maintained through the ACO switch.

4. All Disconnect—Console disconnected from each adjacent console.

If a console is disconnected from one of its adjacent consoles, communication between the two consoles will not be disrupted as the alternate input/output connection can still provide such communication via the remaining adjacent unit. For example, if the PLCC No. 1 ACO is disconnected from the PACC ACO, communication between the two consoles can still occur via the path from the PACC, through the ACO at the SCC, through the ACO at the PLCC No. 1, and finally to the PLCC No. 1. The ACO switch assembly is used primarily for maintenance purposes. It is used to isolate a console completely from the serial data loops or to isolate a certain interconsole segment of the data loop from the system.

The demand display serial data system (figure 9-34) is separate from, but similar to, the command and control serial data system. It interconnects the CISE, PACC, PLCC No. 1, PLCC No. 2, and the EPCE. It is used only for digital display information exchange. Separate sets of triple redundant data lines are used for connecting CISE with the other consoles in the demand display serial data system. (See figure 9-34.) Digital addresses of propulsion, auxiliary, and electric plant system parameters are multiplexed ar serially sent via the data lines to CISE by eac of the listed SCCs. This is done during certai fixed time periods within each second of syste operation. The ECU (1) receives and decodes tl 16-bit serial parameter address, (2) retrieves tl value of the demanded parameter from comput storage, and (3) serially sends the parameter valu back to the proper control console for digit display.

For example, if the PACC operator neede to know the hp output of the GTM 2A, tl operator would refer to the sensor index on tl PACC and find the address needed to read th parameter. For the GTM 2A, this address is 12 The operator would then enter that address in the thumbwheel switches at the digital displa chosen. The address is sent to the ECU. The EC retrieves the value of that parameter from i memory associated with that address. The EC obtains this data in memory from the S/CEs. T ECU then sends that data back to the digit display that requested it.

The digital display does not provide t engineering units or the multiplier. Both t engineering units and multiplier are given with t sensor index on the console. Engineering units a the physical units associated with that addre such as hp or psig. The multiplier locates t decimal point. In the example given, it is ×10 This means that the operator must multiply t reading on the digital display by 100. The addre tables at the consoles are sectionalized into a control, electric plant, GTM, and so forth. T tables list the parameter name, demand displ address, associated alarm set point (if any), a whether the alarm point is a low- or high-le alarm.

Synchronization

Synchronization within the command a control and demand display circuits contain in the PAMISE, PACC, PLCC No. 1, PLC No. 2, EPCC, and the SCC is maintain by system sync pulses and 8192 hertz clo pulses. These sync pulses are generated a master clock circuit. They are sent to t

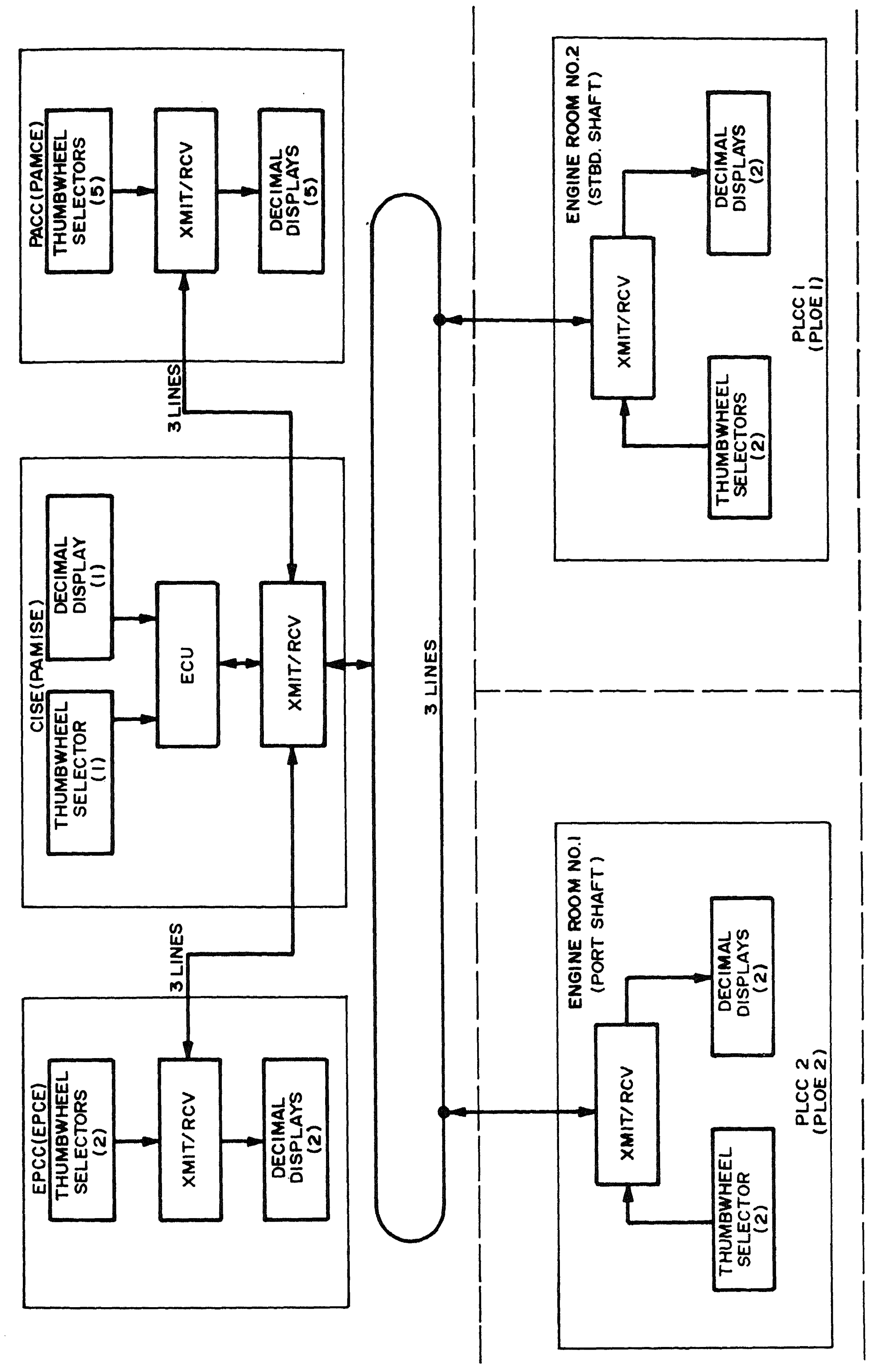

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Figure 9-34.—Demand display serial data system.

various control console serial data circuits (figure 9-35).

The system sync pulse, generated at one pulse per second (pps), is 122 microseconds in duration. As applied in this chapter, a pulse is a repetitive voltage signal of a fixed period which varies from a logic zero to a logic one. The trailing edge of this sync pulse shows time zero of each second of the serial data loops operation.

The hertz clock pulses are used for timing serial data electronic circuitry within each console. That is, the clock pulses allow timing of transmission of the proper information and delivery of received information to its proper destination.

The system master clock circuit is located in the S/CE No. 1 of PAMISE. It sends the synchronization signal to the remainder of the ECSS consoles over a system sync and clock bus network. Identical master clock circuits are in the PLCC No. 1 and PLCC No. 2. They automatically take over series data system synchronizing function if the S/CE No. 1 clock fails. The takeover circuitry is designed so the PLCC No. 1 takes over if the S/CE No. 1 fails; the PLCC No. 2 takes over if the PLCC No. 1 fails.

DATA PROCESSING

The objective of this section is to provide a functional analysis of alarm generation and distribution of data for display and logging. This description analyzes the information flow after the sensory inputs have been signal conditioned (which was discussed earlier).

Alarm Monitoring

Alarm monitoring is performed on some of the engineering plant parameters. After these parameters have been signal conditioned (0 to 10 volts d.c.), they are connected to alarm detector electronics located in the proper S/CE unit. The alarm detector compares the conditioned sensory input voltage to an alarm set point voltage. If this alarm set point is exceeded by the sensory input value (high alarm), an alarm signal is generated. It is routed to the ECU to provide for a printed record. The signal is also routed to provide an audible alarm (horn or siren) and illuminate the proper flashing light indicator. The alarm is a low alarm when the alarm set point value exceeds the sensory input value.

The output of the alarm comparators of S/CEs No. 2 and No. 3 provide hardwire alarm signals to its associated PLCC. Those of S/CE No. 1 provide hardwire alarm signals to the EPCC and the auxiliary panel of the PACC. This alarm output signal causes the proper indicator light to flash and either the horn or siren to sound. The alarms at each PLCC are duplicated at the PACC. The PACC receives the alarm information from each PLCC via the command and control serial data bus. The output alarm signal of the alarm comparator at S/CEs No. 2 and No. 3 are also serially transmitted. This is done by a separate data bus to the ECU to start an alarm log. The S/CE No. 1, however, sends the alarm signals in a parallel format to the ECU to begin the alarm log.

The ECU also functions as a backup alarm detector when failure of an S/CE alarm detection circuit occurs. Since the ECU extracts the sensor input value before the alarm detection circuit, it will compare this value to the alarm set point value stored in memory. If the sensor value exceeds the set point value, the ECU checks to see whether the S/CE alarm detection circuit has generated an alarm signal. When the ECU has determined that the alarm detection circuit has failed, it will generate an alarm override signal. This signal is sent to the PLCC and PACC alarm control logic which sets the alarm and bypasses the defective circuitry.

Some monitored propulsion plant parameters require a time delay. This is to prevent nuisance alarming of selected pressures and liquid levels. This is done by time delay electronic circuitry. This device has the capability of hardwire programming of the amount of time delay needed. The range of selectable time delay available on each circuit is 0.0 to 7.0 seconds in 0.5-second increments. Longer time delays can be provided by interconnecting more than one circuit. This circuitry can be compared to a countdown timer. If a 5-second time delay is programmed and it receives an alarm condition from the alarm

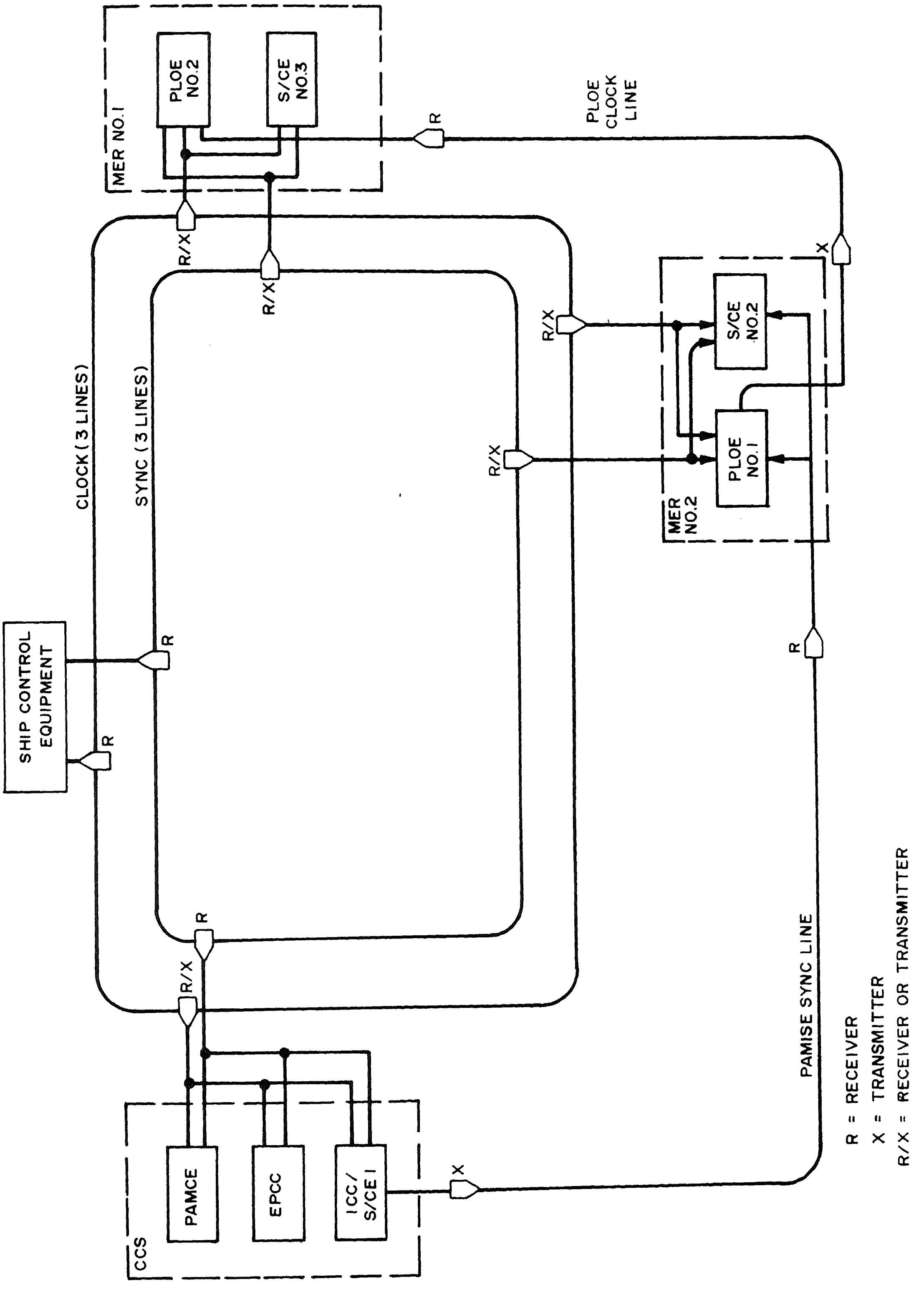

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Figure 9-35.—Clock and synchronization signal distribution.

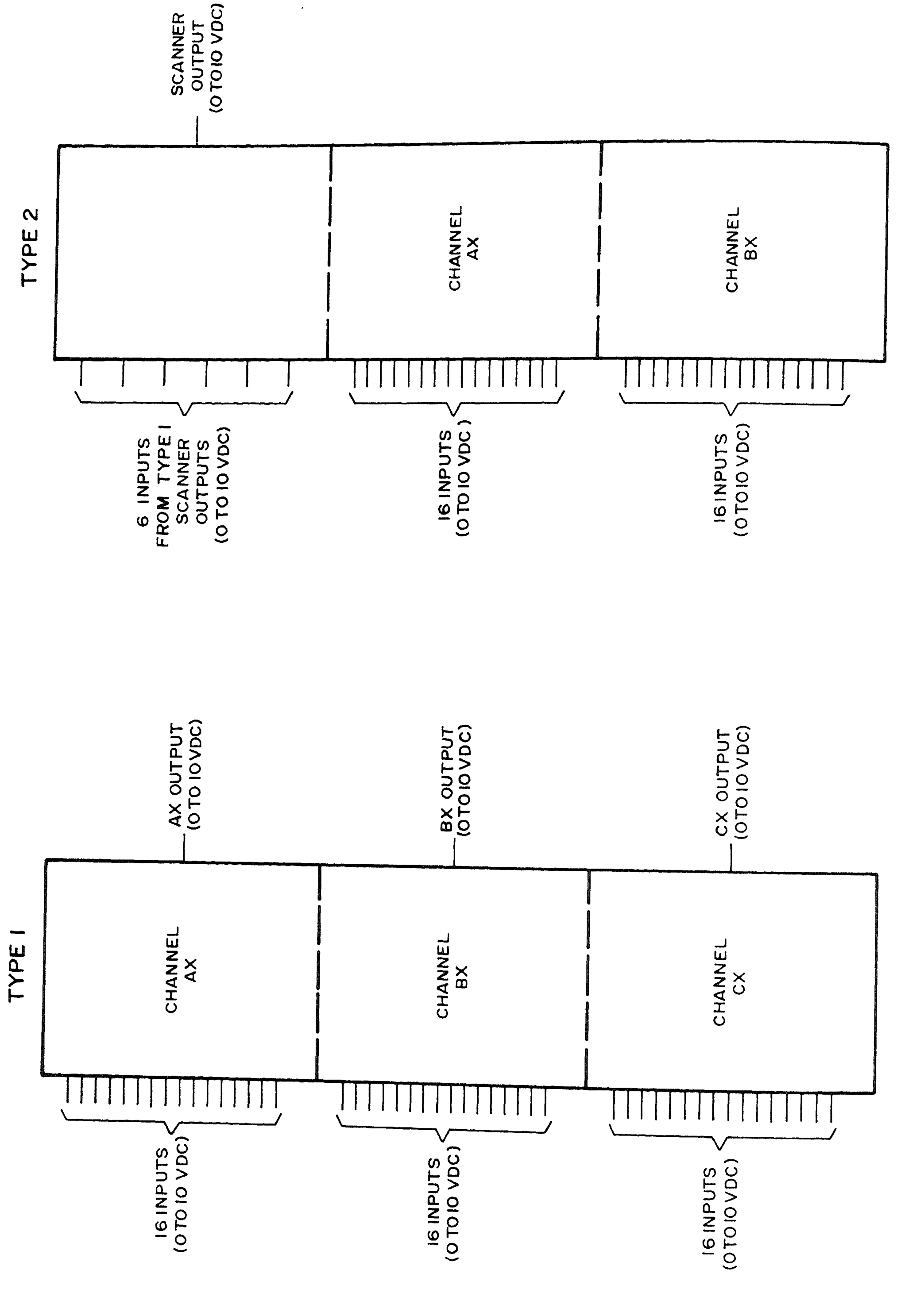

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Figure 9-36.—Analog scanners.

detector, the timer will be released and count to zero. At a count of zero, the alarm condition is sounded. Time delay circuitry includes digital filtering. This prevents electrical noise (negative going signals of less than 3 or 6 milliseconds duration) on the input from the alarm detector line from resetting the alarm time delay countdown (back to 5 seconds using the example above). Without this filtering, the noise could either cause a longer time delay or cancellation of the alarm. The ECU serves as a backup system. It generates the alarm if the alarm time delay circuitry fails.

Scanning and A/D Conversion

For the ECU to obtain its information, the parameters monitored by the S/CEs must be scanned one at a time. Then the information must be converted from an analog voltage value (0 to 10 volts) to a binary digital number (0 to 100 counts). This digital information is then serially transmitted from each S/CE to the ECU for storage in memory.

Scanning is performed at two levels called primary and secondary scanning. Scanning is performed by electronic circuitry called analog scanners. Two types of scanners are used. A block diagram of the Type 1 scanner used for primary and secondary scanning is shown in figure 9-36. The Type 2 scanner used for primary scanning is also shown in figure 9-36.

The Type 1 scanner has three channels with 16 inputs per channel and 1 output per channel. The inputs of the scanners are connected to the outputs of signal conditioner sensory signals (0 to 10 volts d.c.). By control timing pulses generated by the system clock (not shown in the figure), the scanners select 1 of 16 inputs of each AX, BX, or CX channel. That selected input is presented at the output of the channel being presently scanned.

The Type 2 scanner has two channels with 16 inputs per channel. It also has inputs from the outputs of a Type 1 scanner. The Type 2 scanner only has one output. Control timing pulses from the system clock are again used to present a selected input at the output of the Type 2 scanner.

In S/CEs No. 2 and No. 3 scanning is performed on the primary and secondary levels. Three Type 1 scanners and one Type 2 scanner are used (figure 9-37). Primary scanning has channels A1, B1, C1, A2, B2, C2, A3, and B3, with 16 inputs per channel. As each channel is enabled, each of the 16 respective channel inputs is sequentially connected to the output of the scanning system for 7.8 milliseconds. It takes 1 second to scan primary channels A1 through B3. The order of primary scanning is: A3-B3-A1-B1-C1-C2-B2-A2. During primary scan of channel A1, the first three inputs are the scanner outputs of channels A, B, and C in the secondary scanner. During a 1-second period of primary scan, only one input of each of the A, B, and C channels is presented to channel A1. During the next 1-second period of primary scan, the next respective input of each of the A, B, and C channels in the secondary scanner is presented to channel A1. Therefore, the main difference between primary and secondary scanning is that during a 1-second period all the inputs in the primary scanner are monitored; but, only 3 out of 48 inputs in the secondary scanner are monitored during the same 1-second sampling period.

In S/CE No. 1 scanning is done only on the primary level. Two Type 1 scanners and one Type 2 scanner are used (figure 9-36). A block diagram would be represented by deleting the secondary scanner shown in figure 9-37. Then replace the secondary scanner inputs on channel A1 with outputs from signal conditioners. The functional operation of this scanner is the same as discussed for the primary scanner for S/CEs No. 2 and No. 3.

From the outputs of the scanner, the analog voltage (0 to 10 volts d.c.) 7.8-millisecond samplings are passed to an A/D converter. During the 7.8-millisecond period, the A/D electronics converts the analog voltage to an equivalent binary number on a decimal scale of 0 to 1000 counts. For example, if a voltage of 5.47 is presented to the A/D converter electronics, it will output a binary value equal to 547 counts

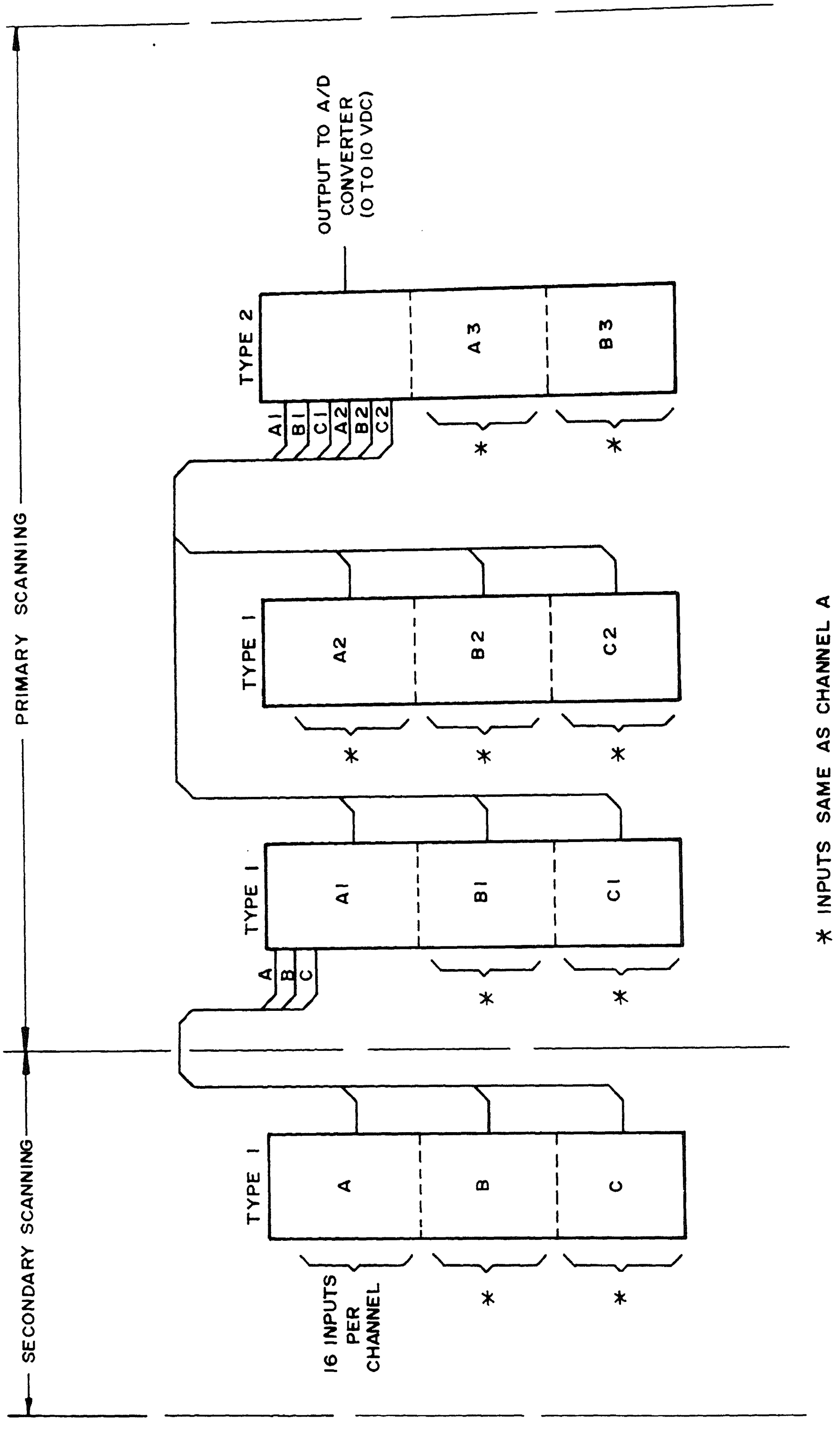

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Figure 9-37.—S/CEs 2 and 3 primary and secondary scanning.

(decimal) on ten weighted bit outputs; these are shown in table 9-2.

Using the above value of 5.47 volts d.c. into the A/D converter, the output is represented by the 1s and 0s above the input line. The binary number output is 1000100011 base 2. This is equal to 547 decimal.

The digital values are then sent to the ECU at the 7.8-millisecond rate over two separate serial data buses. One bus is used for S/CE No. 2 and the other for S/CE No. 3. Since S/CE No. 1 is located in the same enclosure as the ECU, serial transmission of the ten weighted bits is not required; instead, parallel format transmission is used. The serial transmission buses mentioned above are separate from the demand display and the command and control serial data systems. Transmission of information over this serial bus is similar to the method discussed earlier. An exception is that a maximum of 128 words is sent in a 1-second period from the S/CEs No. 2 and No. 3.

To review, remember that most sensory inputs, but not all, enter the S/CEs where they are signal conditioned (converted to a 0- to 10-volt d.c. signal). In the S/CEs, if these parameters have an alarm limit, they are alarm compared. If a parameter changes alarm state, an alarm signal is generated. It is sent to the ECU by a serial data bus dedicated only to alarm changes. The ECU then generates an alarm log. The S/CEs also hardwire this alarm change signal to the proper PLCC, EPCC, or auxiliary section of the PACC. This causes the proper indicator to change state and activates the horn or siren. The PACC receives the alarms from the PLCC via the command and control data bus, except for most of the auxiliary panel alarms. Finally, the S/CEs take the conditioned signals and convert them to digital values by A/D converters. These digital values are sent to the ECU by another serial data bus that does this job only.

OUTPUT CONTROL INTERFACE

So far we have discussed how the ECSS gathers information and how the consoles of the ECSS communicate. This section will analyze how the ECSS communicates commands to the engineering plant equipment. This communication is mainly done by the PLCC in one of three basic types of output depending upon the equipment to be controlled. The PACC controls the auxiliaries directly and not through the PLCC. The three basic types of control output are continuity, logic level, and power output.

1. Continuity—provides a contact closure or opening to be used by the external equipment. An example of this is the main fuel valve check switches. They provide an open/close command signal from the PLCC to the FSEE.

2. Logic level—provides a logic voltage level output, either on or off, to be used by the external equipment. An example of this is the battle override signal from the PLCC to the FSEE.

Table 9-2.—Sample A/D Conversion

Binary No.	1	0	0	0	1	0	0	0	1	1
Output Line	*	*	*	*	*	*	*	*	*	*
Equivalent Binary Weight	512	256	128	64	32	16	8	4	2	1
Demand Value Total 547	512		+		32		+		2 +	1

Note: Asterisk represents output conductors of A/D converter.

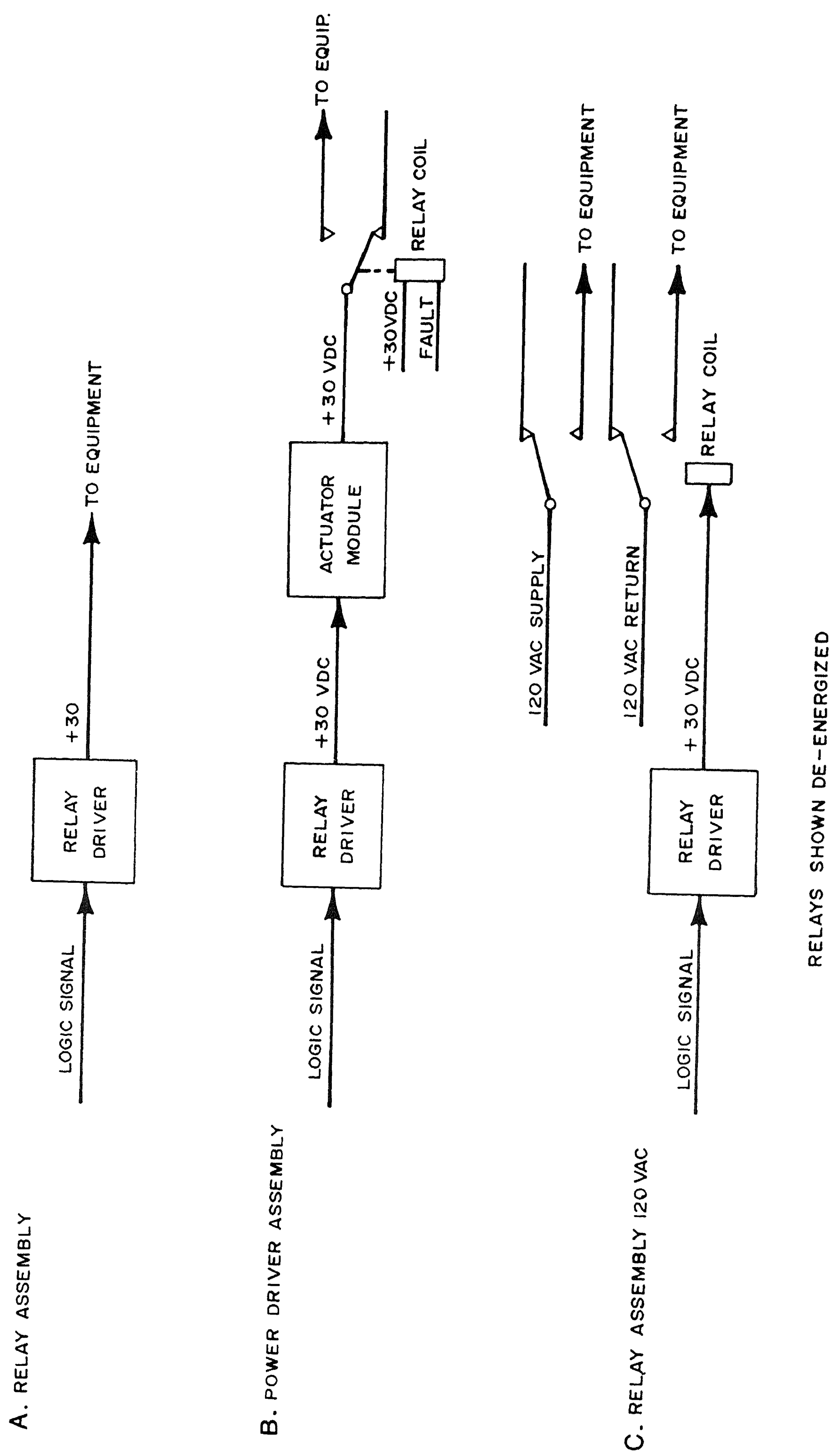

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Figure 9-38.—Power output signals.

3. Power output—provides a control voltage from the ECSS to the external equipment to be controlled. The power output signals are further subdivided into three types (actuator/relay driver, actuator module, and 120-volt a.c. relay driver assembly) as shown in figure 9-38.

a. The actuator/relay driver converts a logic level command to a 30-volt d.c. output. This type of control is used in the IR suppression circuitry at the PACC.

b. The actuator module takes the 30-volt d.c. signal from the actuator/relay driver. In effect, it amplifies it to provide a 30-volt d.c. output with greater current capability. This type of control is used for clutch/brake commands from the PLCC.

c. The 120-volt a.c. relay driver assembly converts a logic level command to 120-volt a.c. output. It uses a relay driver to energize a relay which provides the output. This type of control provides power to the igniters on the GTM.

FUEL SYSTEM CONTROL EQUIPMENT

The fuel system control equipment is not connected to any components of the ECSS. It is, however, an important electronic control console on the *Spruance* class ships; therefore, it is discussed in this chapter as is the damage control console.

The major components of this system include the FSCC, two FO local control panels, and the JP-5 local control panel. These four components are designated by unit numbers for circuit and part identification: FSCC—unit one, JP-5 local control panel—unit two, FO local panel No. 1—unit 3, FO local panel No. 2—unit 4 (power supply 2PS1 is located in unit 2, power supply 3PS1 is located in unit 3). These consoles and panels are an integrated information and control system. They provide operator control and monitoring from local and remote locations. In most cases, information generated by one unit of its system is shared by one or more of the other units. Fuel oil control uses the upper operator's panel of the FSCC and the FO local control panels; JP-5 control uses the lower operator's panel of the FSCC and the JP-5 local control panel.

FUEL SYSTEM CONTROL CONSOLE

The FSCC has three main cabinet assemblies (A1, A2, A3), the fuel oil fill and transfer control panel (A4), and the JP-5 control panel (A5). Figure 9-39 shows the console outline and component location. The three main cabinet assemblies contain the power supplies, electronic hardware, and internal wiring of the FSCC. The fuel oil fill and transfer control panel A4 has the operator controls and indicators for the FO fill and transfer system. The JP-5 control panel A5 has operator controls and indicators for the JP-5 fill, transfer, and service systems.

Power Supplies

The FSCC has eight power supplies located in the power supply drawers. Two supplies are used for each voltage level. They normally operate in parallel, sharing the current load. The LEDs at the power supplies show voltage output. If one supply of a pair should fail, the LED for that supply will extinguish. The other power supply of the pair will automatically supply the load. Isolation diodes between the power supplies prevent the failed supply from absorbing current. Each power supply has an output voltage adjust potentiometer (R1) to calibrate the supply within its specified tolerance.

The FSCC sends +24 volts d.c. power to all three local panels for illumination of indicators controlled by the FSCC. The FSCC also receives +24 volts d.c. power from the three local control panels to operate indicators energized by the local panels.

Card Cage

Section 1A2A1 houses the card cage. It has the 32 printed circuit boards (PCBs) used in

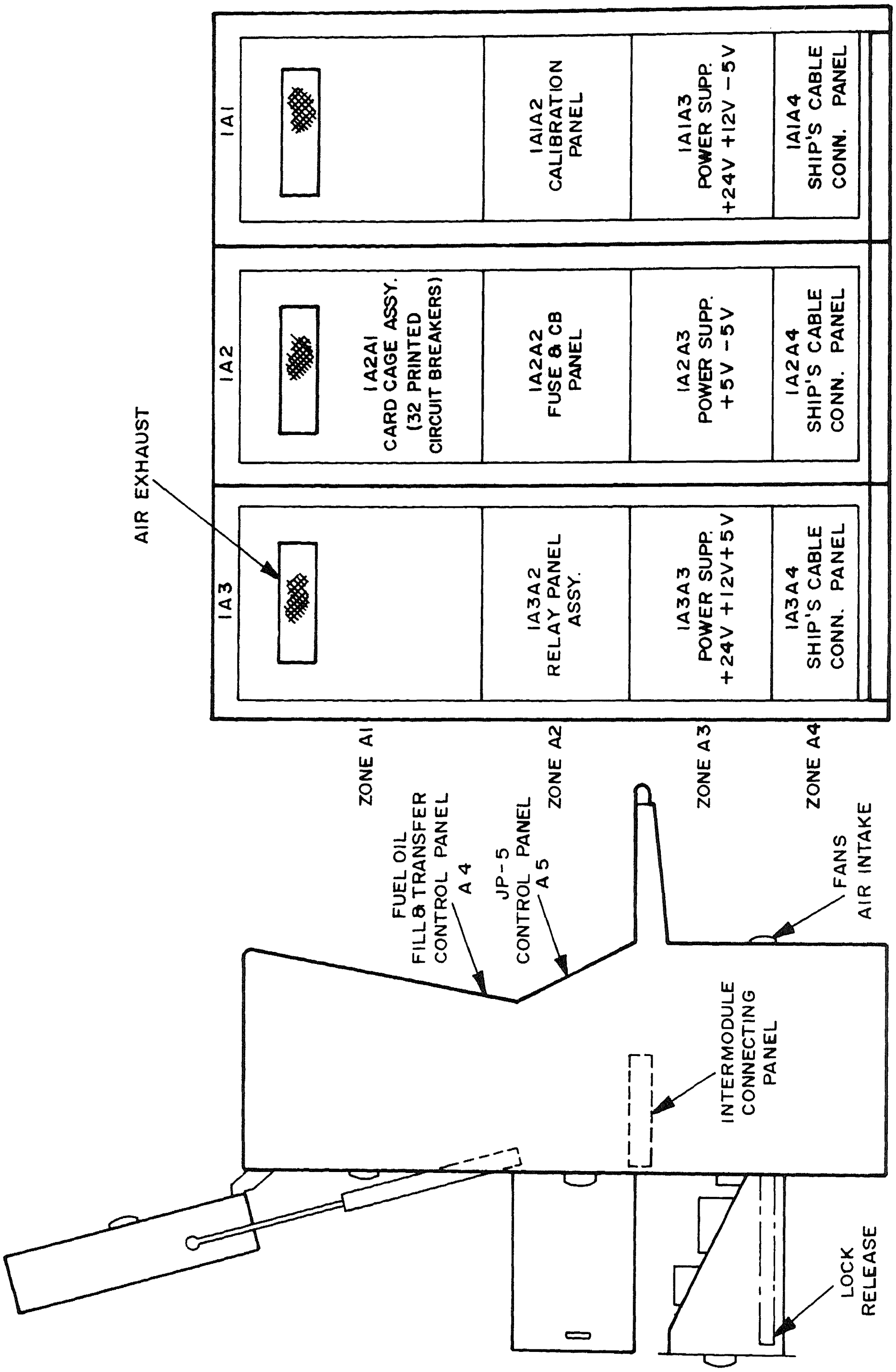

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Figure 9-39.—Fuel system control console—component location.

monitoring, alarm, and control functions. The card cage assembly will swing up for maintenance. The function of particular card types is discussed later in this section.

Circuit Breaker Panel

Section 1A2A2 of the FSCC has the fuse and CB panel. CB1 is the main power CB for the FSCC. Fuses 1 through 10 protect the console from faults in the 120-volt a.c. remote control wiring. The three switches, S1, S2, and S3, turn power on/off to the three power supply drawers.

Relay Panel Assembly

Section 1A3A2 of the FSCC has the relay panel assembly. The nine 24-volt d.c. relays control FO and JP-5 valve closing. They are energized by the auto fill circuits. Associated with each relay is a suppression diode (CR1 through CR9) to prevent damage to the auto fill logic output circuits. The front side of this panel holds the spare fuses for the console.

Calibrate Panel

Section 1A1A2 of the FSCC has the calibrate panel. This panel has the switches and potentiometer used in calibrating meter circuits and setting alarm points for those functions processed by the FSCC.

Storage tank level meter calibration is done using a three-position momentary contact switch, a full scale adjust potentiometer, and the associated zero adjust potentiometer for each tank. If the switch is pushed to the FULL position, you can set the full adjust potentiometer to obtain a full scale reading on the associated panel meter. When the switch is in the ZERO position, you can set the zero adjust potentiometer to obtain a zero panel meter reading.

You can also calibrate the FO receiving tank pressure meter circuits at this panel. A PUSH TO ADJUST FULL SCALE pushbutton is associated with each receiving tank pressure circuit. When the pushbutton is depressed, you can set the panel meter for full scale by adjusting the full scale adjust screw on the panel meter assembly.

From the calibration panel, you can adjust the high seawater, fuel overflow, JP-5 storage tank level HI/LO, and FO receiving tank pressure high hazard alarm set points. When the pushbutton for one of these alarms is depressed, the associated panel meter reads the alarm set point. By turning the corresponding adjust potentiometer, you can adjust the alarm set point to its desired value.

Also located on this panel are two mode switches. These affect the JP-5 storage tank circuits. When in the LOCAL ONLY position, only the FSCC panel meter indicates tank level. When in the LOCAL AND REMOTE position, both the FSCC and the JP-5 local control panel meters function.

Operator's Panels

The upper console operator's panel is used to monitor and control the FO fill and transfer systems. The lower panel contains monitor and control functions for the JP-5 system. These panels have mimics of the associated system, vertical reading meters to display system parameters, indicator lights to display system status, and pushbuttons to remotely control motor-operated equipment.

FUEL OIL LOCAL CONTROL PANELS

The two FO local control panels are similar. The FO local control panel No. 1 has control and monitor equipment for the No. 1 FO transfer equipment; FO local control panel No. 2 has control monitor equipment for the No. 2 transfer equipment. Information is exchanged between each of the local panels and the FSCC.

These panels are bulkhead mounted. They have an upper and lower front panel and a metal enclosure that houses the power supplies and

electronic circuits. Figure 9-40 is an outline of the FO local control panel.

Power Supplies

Each FO local control panel has four power supplies, one for each d.c. voltage level used (+5 V, −5 V, +12 V, +24 V). The local +5 volt, −5 volt, and +12 volt supplies are the same type as those in the FSCC. The 24-volt supply used in the local panels is functionally similar to the FSCC 24-volt supply; however, the maximum power output is less. Each power supply voltage is adjustable. Each local panel sends 24 volts d.c. power to the FSCC. This is used to illuminate remote indicators controlled by the local panel.

Card Cage

The card cage, mounted on a hinged panel with the calibrate panel, houses the 13 PCBs for each FO local control panel. These cards are used for monitor and control functions.

Power Distribution Panel

Each FO local control panel assembly houses a power distribution panel. This panel has the

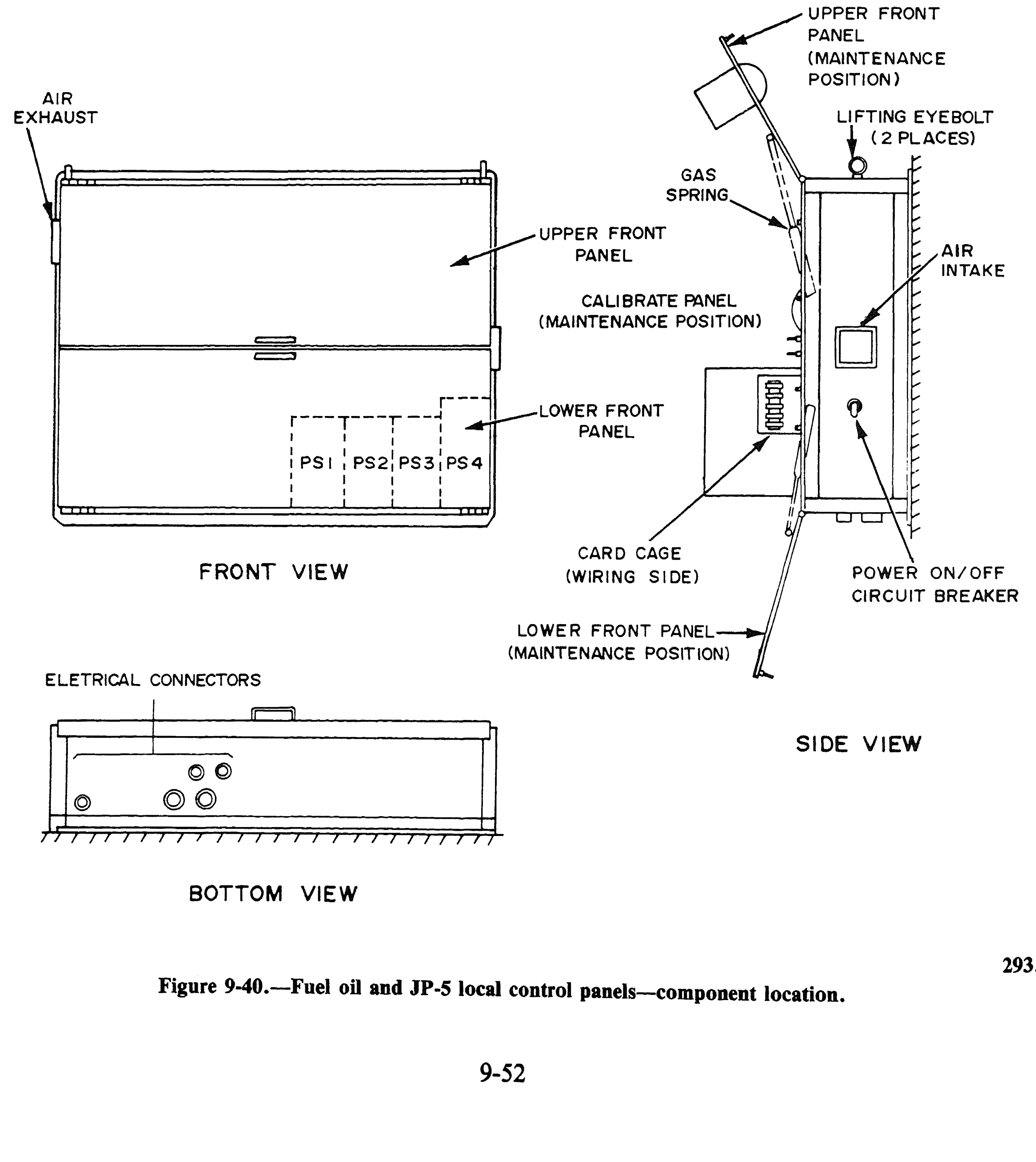

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Figure 9-40.—Fuel oil and JP-5 local control panels—component location.

terminal boards for panel connections and the protective fuses for that particular panel.

Power to a local panel is controlled by one a.c. CB, CB1. This CB is located on the right side of the enclosure (figure 9-40).

Calibrate Panel

Each FO local control panel has a calibrate panel. It serves the monitor and alarm circuits of the local panel in the same manner that the FSCC calibrate panel serves the FSCC circuits. The panel is used to calibrate associated service tank level, transfer pump pressure, FO heater temperature, and purifier pressure meter circuits. You can also set service tank level HI/LO alarms, transfer pump pressure alarms, and purifier discharge pressure alarm set points at this panel. All seven meter circuits have mode switches for selection of LOCAL AND REMOTE or LOCAL ONLY displays.

Operator's Panel

The upper front panel of each FO local control panel has the meters, indicators, and pushbuttons necessary to operate the transfer system. The panel is arranged as a mimic of the particular transfer system it controls.

JP-5 LOCAL CONTROL PANEL

The JP-5 local control panel is similar in construction to the FO local control panels. The monitoring and control functions of this panel are for the JP-5 fill, transfer, and service systems. This panel exchanges information with the FSCC only.

Power Supplies

The JP-5 local control panel has four power supplies, one for each d.c. voltage level used (+5 V, −5 V, +12 V, +24 V). The arrangement of these power supplies in the enclosure is similar to the FO local control panel arrangement. Twenty-four volts is sent to the FSCC for illumination of indicators controlled by the local panel. All four power supplies are energized by the CB1.

Card Cage

The card cage, mounted on a hinged panel common with the calibrate panel, houses the 12 PCBs used for control and monitor functions.

Power Distribution Panel

The JP-5 local control panel has a power distribution panel. It is similar to those in the FO local control panels.

Calibrate Panel

The calibrate panel of the JP-5 local control panel is similar in function to those in the FSCC and FO local control panels. The only circuits serviced by this panel are the JP-5 service tank level high and low alarm functions. No mode switches are on this panel. This is because the only JP-5 service tank level meters are at the JP-5 local control panel.

Operator's Panel

The upper front panel of the JP-5 local control panel has the meters, gauges, indicators, and pushbuttons necessary to operate the JP-5 fill, transfer, and service systems. This panel is the primary control center for JP-5 transfer and service operations. This is because the FSCC only has provisions for limited monitoring and terminating of these operations.

All pressure monitoring at the JP-5 local control panel is done with pressure gauges. At the top of the enclosure are gauge cutout valves for each of the gauges.

TANK LEVEL MONITORING AND ALARM

The FO fill and transfer control system measures levels in each of 24 FO storage tanks, 4 FO service tanks, 2 JP-5 storage tanks, and 2 JP-5 service tanks. Individual tank levels are displayed by vertical panel meters at the FSCC, the JP-5 local control panel, and the FO local control panels. All tank level circuits function in a similar manner. They convert analog information from a tank level transmitter to a meter display. Also, some of the circuits have associated hazard alarms for high- or low-level conditions.

These electronic circuits are located either at the FSCC or one of the local panels, depending

Table 9-3.—Tank Level Monitoring Circuit Locations

TANK TYPE	CIRCUIT LOCATION	HAZARD ALARM	REMOTE DISPLAY
FO Storage, Receiving	FSCC	High Seawater	None
FO Storage, Mid Position	FSCC	None	None
FO Storage, Last Position	FSCC	Fuel Overflow	None
FO Service, Fwd	*FOLP 1	High, Low	FSCC, FOLP 2
FO Service, Aft	*FOLP 2	High, Low	FSCC, FOLP 1
JP-5 Storage	FSCC	High, Low	JP-5 Local
JP-5 Service	JP-5 Local	High, Low	FSCC (alarm only)

*FOLP Fuel Oil Local Control Panel

upon the particular level function. Table 9-3 is a list of the types of level measuring circuits, their locations, associated hazard alarms, and remote displays.

Tank Level Transmitters

Each of the level monitored tanks has a level transmitter. A typical transmitter section has a voltage divider resistor network extending the length of the section. Magnetic reed switches are tapped at 1-inch intervals along the resistor network. The reed switches are sequentially connected through series resistors to a common conductor. This network is enclosed in a stem that is mounted vertically in the tank. A float with bar magnets rides up and down the stem as the level changes.

In operation, a calibrated voltage is supplied to the ends of the divider network from an external source (the FSCC or a local panel). As the float moves up or down the stem, the reed switches are closed in a two-at-a-time, three-at-a-time, two-at-a-time sequence. When two switches are closed, the effective tap point is halfway between the two switches. When three switches are closed, the effective tap point is at the middle of the three. As a result, the effective tap point changes in half-inch increments. The common conductor voltage is, therefore, proportional to the float level within a half-inch of travel. This voltage provides tank level information to the system.

The physical arrangement of many tanks necessitates the use of more than one transmitter section to measure the full range. When multiple sections are used, they are electrically connected as one continuous divider network.

Two types of floats are used. In noncompensated tanks, the float is designed to float at the surface of the FO or JP-5. For seawater compensated tanks, the float is designed to stay at the seawater/FO interface.

Service and Storage Tank Level Monitoring Circuits

The signal from the level transmitter is sent to a level monitoring circuit in either the FSCC, FO local panel No. 1 or No. 2, or the JP-5 local control panel, depending upon the particular tank (see table 9-3). This circuit, in turn, drives the associated panel meter(s), starts the visual and audible indications for a hazard alarm, provides sensor circuit fault indication, and provides the meter and alarm calibration. The following paragraphs describe a typical tank level monitoring circuit (figure 9-41).

NORMAL METER DISPLAY.—The calibrate panel provides the voltage for the level transmitter voltage divider network. The voltage level is about 4 volts at one end and 20 volts at the other. These voltages are adjustable. They are set using the SCALE ADJUST switch to give zero and full meter readings corresponding to switch position. Adjustments are made using the FULL SCALE ADJUST and ZERO ADJUST potentiometers. This is done while the switch is held in the FULL or ZERO position accordingly.

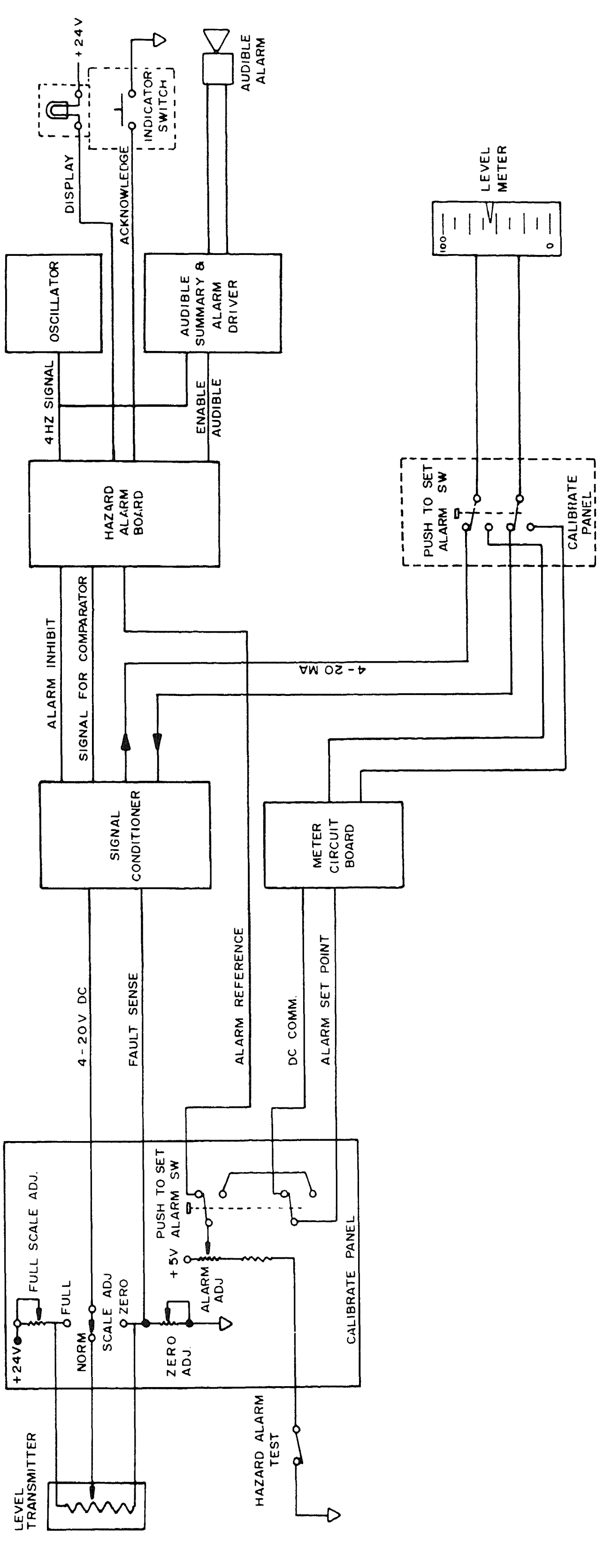

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Figure 9-41.—Typical tank level monitoring circuit.

The third transmitter wire provides a voltage signal that corresponds to tank level. When the float is at the bottom of the divider assembly, the level signal is at the 4-volt level. It is at the 20-volt level when the float is at the top. Thus, the level ranges from 4 volts for an empty tank to 20 volts for a full tank. This 4- to 20-volt d.c. signal goes to the signal conditioner. One output of the signal conditioner is a 4- to 20-mA signal. It is proportional to the 4- to 20-volt d.c. level input that goes to the panel meter.

For tank level circuits with more than one meter, a mode switch on the calibrate panel will send the 4- to 20-mA signal to both local and remote meters in one position. The mode switch also limits the signal path to only the local meter when in the other position.

HAZARD ALARM.—Another output of the signal conditioner serves as a level signal for the hazard alarm board. The hazard alarm board compares this signal to an alarm reference signal. If the level signal drops below the alarm reference, the hazard alarm board outputs an audible enable signal to the audible summary and alarm driver. This driver energizes the audible alarm at a 4-Hz rate. At the same time, the hazard alarm board flashes the indicator light at a 4-Hz rate. Depressing the pushbutton indicator provides an acknowledge signal to the hazard alarm board. This de-energizes the audible alarm. Then the indicator light illuminates steadily. If the level signal into the hazard alarm board raises back above the alarm reference, the indicator light extinguishes.

For tank level circuits with remote alarm indicators, the display signal is sent to the remote indicator. The enable audible signal is sent to the audible summary and alarm driver of the remote panel to energize the remote audible alarm. The remote acknowledge signal is fed back to the hazard alarm board for remote acknowledgement of the alarm.

Depressing the HAZARD ALARM TEST pushbutton opens the return for the alarm reference. This causes this signal to go high. The hazard alarm board, therefore, senses a hazard alarm condition and begins the 4-Hz audible and flashing light indications. The alarm must be acknowledged to silence the audible alarm and steady the indicator light. Releasing the HAZARD ALARM TEST pushbutton removes the alarm test.

When the PUSH TO SET ALARM switch is depressed, the alarm reference signal is routed to a meter circuit board. Here it is converted to a current signal. The PUSH TO SET ALARM switch at the same time connects the meter to the meter circuit board output. The meter reads the alarm threshold setting directly.

Both high- and low-level hazard alarms are used in the system. They function in a similar manner. For a high-level alarm, the alarm reference network is reversed. Depressing the HAZARD ALARM TEST causes the alarm reference to go low.

FAULT CONDITIONS.—The level meter circuits are designed with elevated zero readings. A meter signal of about 4 mA is required to deflect the needle to the zero scale reading. If no meter current is supplied, the needle reads below scale.

If a level transmitter circuit opens, current stops flowing. The fault sense signal from zero adjust resistor goes to common. When the signal conditioner detects this change, it drives the meter current to zero and inhibits the hazard alarm. The operator is alerted to a transmitter circuit fault only by a below scale indication on the meter.

Drain Tank Level Monitoring

The FO purifier drain tanks are monitored for an 80% FULL or 95% FULL condition (figure 9-42). The JP-5 drain tank is monitored for a 95% FULL condition.

LEVEL SENSORS.—The level sensors for the drain tank are single station float switches. The float switches are positioned in the tanks at the level corresponding to their function. The 95% FULL switches have a terminal resistor used in fault sensing.

80% LEVEL INDICATORS.—The 80% FULL circuits have a float switch, an indicator light, and a 24-volt d.c. power input. When the float switch closes, the indicator light illuminates. No alarms are associated with this circuit.

95% FULL HAZARD ALARMS.—When the 95% FULL float switch contacts close, a 24-volt d.c., 95% FULL alarm signal is sent to the fault and hazard alarm board. This board will output a fault alarm signal to the audible summary and alarm driver. The 95% FULL

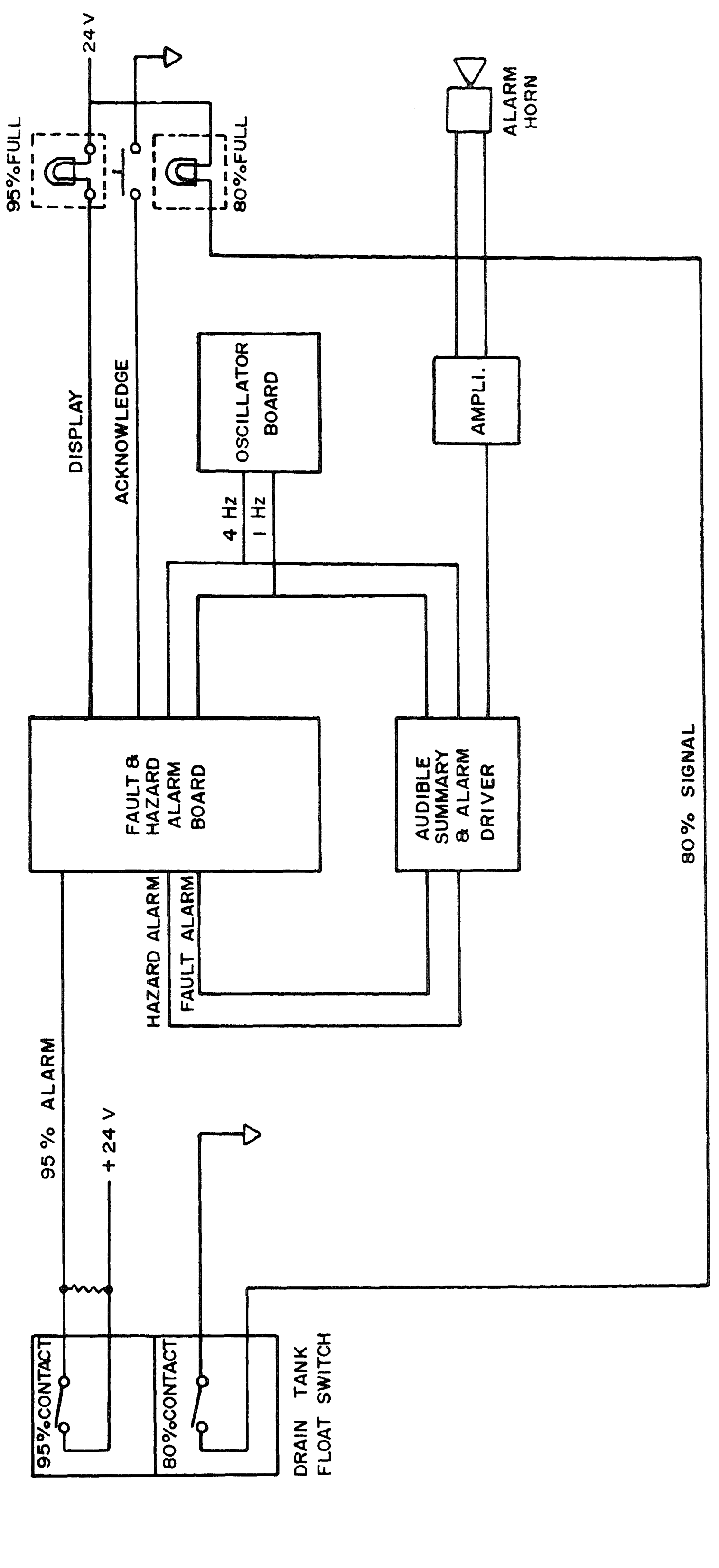

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Figure 9-42.—Fuel oil drain tank level monitoring circuit.

Table 9-4.—Pressure Monitoring Circuit Locations

CIRCUIT FUNCTION	CIRCUIT LOCATION	HAZARD ALARM	REMOTE DISPLAY
FO Receiving Tank	FSCC	High Pressure	None
FO Transfer Pump Inlets	*FOLP 1,2	High Pressure	FSCC
FO Transfer Pump Discharges	*FOLP 1,2	High Pressure	FSCC
FO Purifier Inlets	*FOLP 1,2	None	FSCC
FO Purifier Discharges	*FOLP 1,2	High Pressure	FSCC

*FOLP - Fuel Oil Local Control Panel

indicator will flash at the 4-Hz rate. The audible summary and alarm driver energizes the amplifier and speaker (for local panels) at the 4-Hz rate. Acknowledgement of the alarm will de-energize the amplifier and cause the indicator light to illuminate steady. When the 95% FULL contact opens, the indicator light extinguishes.

FAULT ALARMS.—Unlike the service and storage tank level monitoring circuits, the 90% FULL circuits show a sensor line fault with a fault alarm. Since the 95% FULL sensor circuits have terminal resistors at the tank junction box, a quiescent current flows in the sensor lines even when the contacts are open. If the sensor lines fault by opening, this current stops flowing. The fault and hazard alarm board senses this condition and starts a fault alarm. For this fault alarm, the indicator light illuminates at the 1-Hz rate. The audible circuit will be energized at the 1-Hz rate. The acknowledge signal from the pushbutton indicator de-energizes the audible but not the flashing indicator display. The only way to extinguish the light is to eliminate the fault condition. Depressing the FAULT TEST pushbutton sends a 5-volt d.c. fault alarm test signal to the hazard and fault alarm board. This will initiate a fault alarm. Figure 9-42 shows a simplified FO purifier drain tank monitoring circuit. The actual circuits include provisions for remote alarm display and acknowledgement. The JP-5 drain tank monitoring circuit is similar, except no 80% FULL circuit exists.

PRESSURE MONITORING AND ALARM GENERATION

Pressure is monitored and displayed for the FO receiving tanks, FO transfer pump inlets and discharges, and FO purifier inlets and discharges. All but the purifier inlets are provided with HIGH PRESS hazard alarms. These circuits are all functionally similar. Table 9-4 is a list of circuit locations and remote displays.

Pressure Transducers

The pressure tranducers used in these circuits are the same type used in the ECSS. These pressure transducers are supplied with system +24 volts d.c. They regulate current flow between this +24 volts and common. This current is regulated to be proportional to the pressure input. The current is varied from 4 to 20 mA as the pressure changes from the low extremity of its range to the maximum. Current regulation is accomplished by circuits located within the transducer.

Pressure Monitoring Circuits

The pressure signal from the pressure transducer is sent to a pressure monitoring circuit in either the FSCC or one of the FO local control panels, depending upon the particular parameter (table 9-4). This circuit provides meter calibration, starts hazard alarms, and provides alarm point adjustment. It also gives fault condition indication. The following paragraphs describe a typical pressure monitoring circuit (figure 9-43).

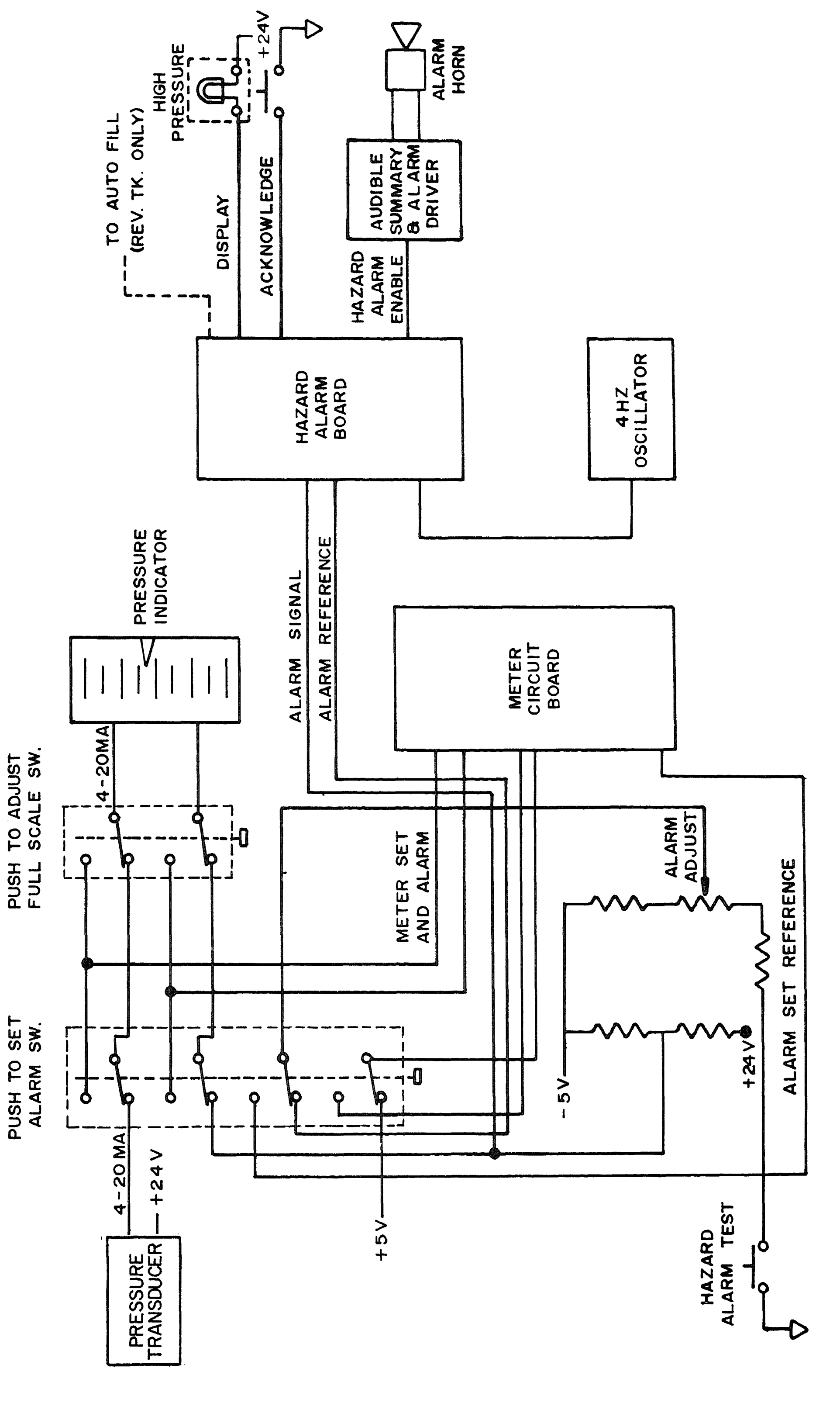

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Figure 9-43.—Typical pressure monitoring circuit.

NORMAL METER DISPLAY.—Since the pressure signal provided by the pressure transducer is a 4- to 20-mA current representing pressure, no signal conditioning is required. The signal is routed through the PUSH TO SET ALARM switch, the PUSH TO ADJUST FULL SCALE switch, and then through the panel meter (and remote meters if used). The return path is to −5 volts d.c. through a fixed resistor. This resistor provides a voltage signal proportional to pressure for alarm operation.

The PUSH TO ADJUST FULL SCALE switch is used to calibrate the meter full scale reading. When depressed, this switch disconnects the meter (or meters) from the transducer. It connects them to a 20-mA meter setting signal from the meter circuit board. The full scale setting is made at the meter's mechanical full scale adjustment screw.

When remote meters are used, a mode switch is used for selection of LOCAL AND REMOTE or LOCAL ONLY displays.

HAZARD ALARM.—The hazard alarm function is similar to that of the tank level monitoring circuits. The alarm signal for the hazard and alarm board is generated by the voltage drop across the fixed resistor in the meter current return path. The alarm reference is established by a voltage divider between −5 volts d.c. and common. Depressing the HAZARD ALARM TEST pushbutton opens the return for the alarm reference voltage divider. This causes the reference to go low and the hazard alarm to be started.

When the PUSH TO SET ALARM switch is depressed, the panel meter is again connected to the output of the meter circuit card. The meter circuit card is programmed to output a current signal proportional to the alarm reference voltage. Then meter displays the actual alarm set point. You can adjust it to the required value using the ALARM ADJUST potentiometer.

FAULT CONDITION.—An open circuit in the transducer circuit stops meter current flow. The meter displays a below scale reading during this fault condition with no fault alarm. No hazard alarm is started, as the hazard alarms are for high pressure.

JP-5 Filter/Separator Alarm Circuits

The JP-5 transfer and service filter/separators are monitored for high differential pressure. The sensors used are differential pressure switches, set to actuate at 15 psid. When the sensor contacts close, the associated filter/separator alarm circuit in the JP-5 local control panel will start a hazard alarm. These circuits are also provided with the 1-Hz fault alarm. Functionally, the filter/separator alarm circuits operate the same as the drain tank level 95 percent circuits.

FUEL OIL TEMPERATURE MONITORING

Temperature of the FO discharged from the two FO transfer heaters is monitored by the system. It is displayed at the associated FO local control panel and the FSCC (figure 9-44). The meter circuitry is located in the associated FO local control panel.

Temperature Sensors

The temperature of the FO is sensed by the RTDs, similar to the type used in the ECSS. Associated with each RTD is a signal conditioner. It uses system 24 volts d.c. to regulate a 4- to 20-mA output at a value proportional to the RTD resistance.

Temperature Monitoring Circuits

The monitoring circuit for FO heater No. 1 is located in FO transfer local panel No. 1; the No. 2 heater circuit is in local panel No. 2. Each circuit has a remote display at the FSCC.

Since the temperature signal from the signal conditioner is at a 4- to 20-mA level, it is routed through the PUSH TO SET FULL SCALE switch to the panel meters. A mode switch allows

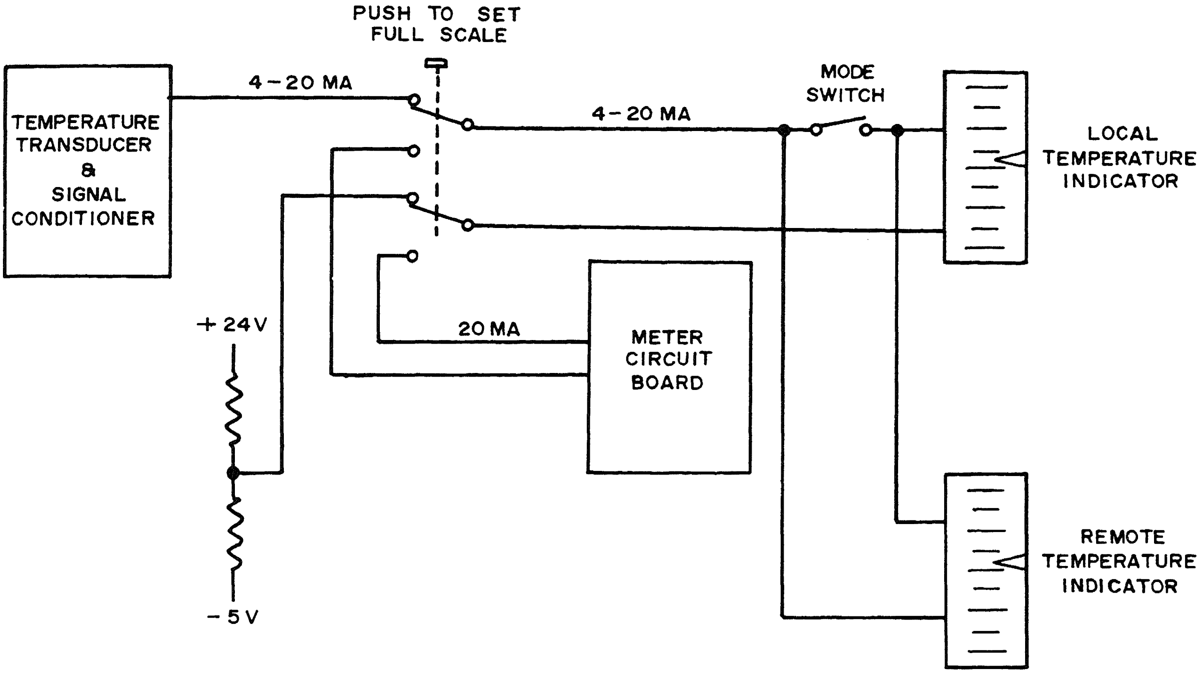

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Figure 9-44.—Temperature monitoring circuit.

selection of LOCAL AND REMOTE or LOCAL ONLY displays. The meter current return is through a fixed resistor to −5 volts.

When the PUSH TO SET FULL SCALE pushbutton is depressed, a 20-mA signal is routed from the meter circuit board to the meter. You can adjust full scale by using the mechanical full scale adjust screw on the meter.

REMOTE CONTROL OF EQUIPMENT

Remote control of selected valves, pumps, and purifiers is provided by pushbuttons at the FSCC and the local panels. The 120-volt a.c. control signals from the pushbuttons energize control relays in the associated motor controllers. Some automatic valve control is provided by the auto fill circuitry.

Pump and Purifier Control

Each of the pump and purifier motors has an associated motor controller. These controllers have selector switches. They enable only the controller pushbutton when in the LOCAL position and only the remote pushbuttons when in the REMOTE position.

If the selector switch is in the REMOTE position, depressing one of the remote ON pushbuttons energizes a run relay in the controller. This run relay picks up the main contactor and the motor will start. At the same time, an auxiliary contact on the main contactor closes, illuminating the ON light on the panel pushbutton indicator. Depressing one of the OFF pushbuttons picks up a stop relay in the controller. This de-energizes the main contactor. The auxiliary contacts extinguish the ON panel indicator lights, then the OFF panel lights illuminate.

Table 9-5 is a list of the pump and purifier remote controls available to the FSCC and the local panels.

Remote Valve Control

You can remotely control each motor-operated valve in the FO fill and transfer and JP-5 systems from the FSCC and/or one of the local panels. The motor-operated valves include the main fill valve, FO receiving tank cutout valves, fuel service tank fill valves, and JP-5 storage and service tank fill valves.

Associated with each motor valve operator is a controller with OPEN and CLOSE pushbuttons. Depressing the OPEN pushbutton picks up and latches the OPEN contactor. Then the motor turns the valve in the open direction. When the valve has reached the open position, a valve travel limit switch opens. The OPEN contactor will drop out. A second limit switch completes the circuit to the OPEN panel light on the controller. A third limit switch provides a CLOSE signal for remote indicators. Depressing the CLOSE pushbutton starts a similar sequence in the close direction.

Also, you can begin the open/close functions by energizing the open or close relay in the controller. These relays are controlled by the OPEN and CLOSE pushbutton indicator on the FSCC and/or local control panels.

The valve motor controllers provide protection for overtorque and overload conditions. If these conditions are reached, the control circuit is interrupted and the contactor de-energized.

The controller for the main fill valve allows partial opening and closing of the valve. The contactors do not latch in. The operator must maintain them by keeping the local or remote pushbutton depressed until the valve reaches the desired position. Valve travel limit switches function to prohibit travel beyond the full open/close position and to energize the OPEN/CLOSE indicator lights. You can also close the main fill valve by the auto fill circuitry.

MANUAL VALVE STATUS INDICATIONS

The primary manual valves used in FO transfer and recirculating operations are equipped with open and closed limit switches. These switches provide open/close signals to the associated FSCC and FO local control panel indicator lights when the valve is in the fully open or fully closed position.

The JP-5 control panel at the FSCC and the JP-5 local control panel also have some manual valve status indicator lights. These valves are not provided with limit switches. The operator must set the pushbutton indicator at the JP-5 local control panel to the proper status. This switch provides the open/close signal to the associated indicator at the FSCC.

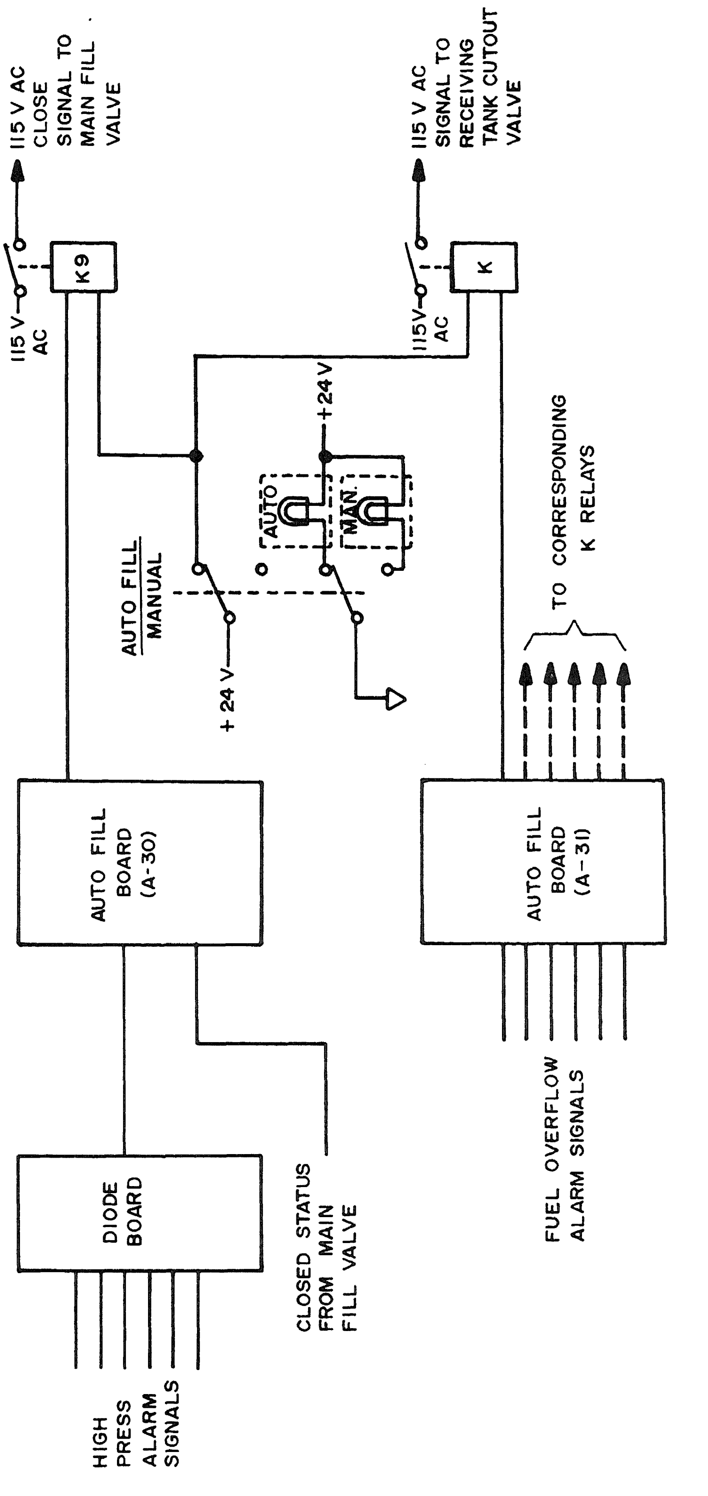
FUEL OIL AND AUTO FILL CIRCUIT

The FO auto fill circuit (figure 9-45) is located in the FSCC. When enabled, it provides two

Table 9-5.—Pump and Purifier Remote Control Locations

EQUIPMENT	FSCC	FO LOCAL PANEL	JP-5 LOCAL PANEL
FO Transfer Pumps	ON/OFF	ON/OFF	---
FO Purifiers	OFF only	ON/OFF	---
Biocide Pump	ON/OFF	---	---
JP-5 Transfer Pump	OFF only	---	ON/OFF
JP-5 Service Pump	OFF only	---	ON/OFF

NOTE: All Pumps and Purifiers have OFF/ON Control at the associated motor controller.



RELAY IDENTIFICATION	
K1 AFT. PORT	K4 AFT. STBD.
K2 MID. PORT	K5 MID. STBD.
K3 FWD. PORT	K6 FWD. STBD.

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Figure 9-45.—Fuel oil auto fill circuit.

functions: it closes the main fill valve as necessary to relieve a HP condition in any FO receiving tank, and it closes the cutout valve for a tank bank when that bank is nearly full.

Diode board A12 receives HIGH PRESS hazard alarm signals from each of the six receiving tank pressure hazard alarm boards. If an alarm signal is present on any one or any combination of these inputs, the diode board outputs a signal to the auto fill board A30. The auto fill board switches the K9 relay return to common. If the auto fill pushbutton indicator is in the auto fill mode, relay K9 picks up. The contacts of relay K9 outputs a 120-volt a.c. close signal to the main fill valve controller. The valve will turn in the close direction until the following conditions are met: (1) all alarm inputs are removed from the diode board, (2) the auto fill board receives a closed status from the main fill valve, or (3) the valve reaches the closed limit switch, de-energizing the controller.

The auto fill board A30 received inputs from each of the FO last position storage tank hazard alarm cards. If a FUEL OVERFLOW alarm signal is present on one of these inputs, the auto fill board switches the corresponding K relay return to common. If the auto fill mode was selected, the K relay for that tank bank outputs a 120-volt a.c. close signal to the receiving tank cutout valve for the tank bank. The valve will close fully, ending filling for that bank. When the valve has closed, a closed signal from the valve limit switch causes the auto fill board to de-energize the K relay. Figure 9-45 identifies the K relay for each tank bank.

JP-5 AUTO FILL CIRCUIT

The JP-5 auto fill circuit is also located in the FSCC. When enabled, its function is to close the fill valve to a JP-5 storage tank when that tank is full.

This circuit functions in the same manner as the receiving tank cutout valve circuits of the FO auto fill. If one of the JP-5 storage tank monitoring circuits starts a high-level hazard alarm, the hazard alarm card for that circuit outputs an alarm signal to the auto fill board A31. The auto fill board will energize a K relay. This causes the fill valve for that tank to close. When the valve reaches the closed position, a signal from the valve limit switch causes the auto fill board to de-energize the K relay. Relay K8 is used for the starboard tank; relay K7, for the port.

OPERATION

This section is limited to general procedures for the FSCC and local panel power application, turnoff, and self-test. You can find detailed instructions for starting, operating, and securing this equipment in NAVSEA 0915-022-7010.

Power Application

The FSCC is energized from the fuse and CB panel. The three power supply panel switches (S1, S2, and S3) should be in the ON position. Placing the main power CB (CB1) in the ON position then energizes the FSCC. All power supply indicator lights should be on. Since application of power to the console may alarm some circuits, all flashing pushbutton indicators should be depressed to reset the alarm circuitry.

Energizing the JP-5 local control panel and the FO local control panels is done by placing the a.c. power CBs in the ON position. To reset any alarms, depress any flashing pushbutton indicators.

Self-Tests

The FSCC and the three local panels are equipped with alarm and lamp tests. Depressing the HAZARD ALARM TEST pushbutton causes each hazard alarm circuit in the associated panel to start a hazard alarm (4-Hz flashing indicator and 4-Hz tone). You must acknowledge each hazard alarm. This test also starts associated remote hazard alarms. Depressing the FAULT ALARM TEST pushbutton causes each fault alarm circuit in the associated panel to start a fault alarm (1-Hz flashing indicator and 1-Hz tone). Releasing the pushbutton will end this test. Depressing the LAMP TEST pushbutton lights all indicator lights not checked by one of the alarm tests.

Normal Securing

The FSCC is secured by placing the main power CB to the OFF position. The local panels

are secured by placing the AC POWER switch to the OFF position.

DAMAGE CONTROL CONSOLE

This section describes the major components and circuit functions of the DCC located in the CCS, adjacent to the FSCC. The DCC operates as an independent system from the FSCC and the ECSS. The only interface between the DCC and the ECSS is information received for GTM fire conditions. The FSCC and the DCC are both manufactured by the same vendor. They have many similar hardware items and circuit designs.

CONSOLE DESCRIPTION

The DCC (figure 9-46) has three cabinet assemblies bolted together to form the console. These three sections, designated 1A1, 1A2, and 1A3, contain the card cages, power supplies, fuse and CB panel, and interconnection panels. These components are accessible by swingout doors and pullout power supply drawers located on the back side. On the front side of the console are two operator's panels, the hazard detection panel (1A4) and the firemain panel (1A5). These panels have all the meters, indicators, and switches needed for normal operation of the panel.

Power Supplies

There are nine d.c. power supplies in the DCC located in the power supply drawers. There are two power supplies each for +5 volts, −5 volts, and +12 volts. Three power supplies are used for the +24 volts. Each power supply has an adjustment potentiometer for maintenance calibration.

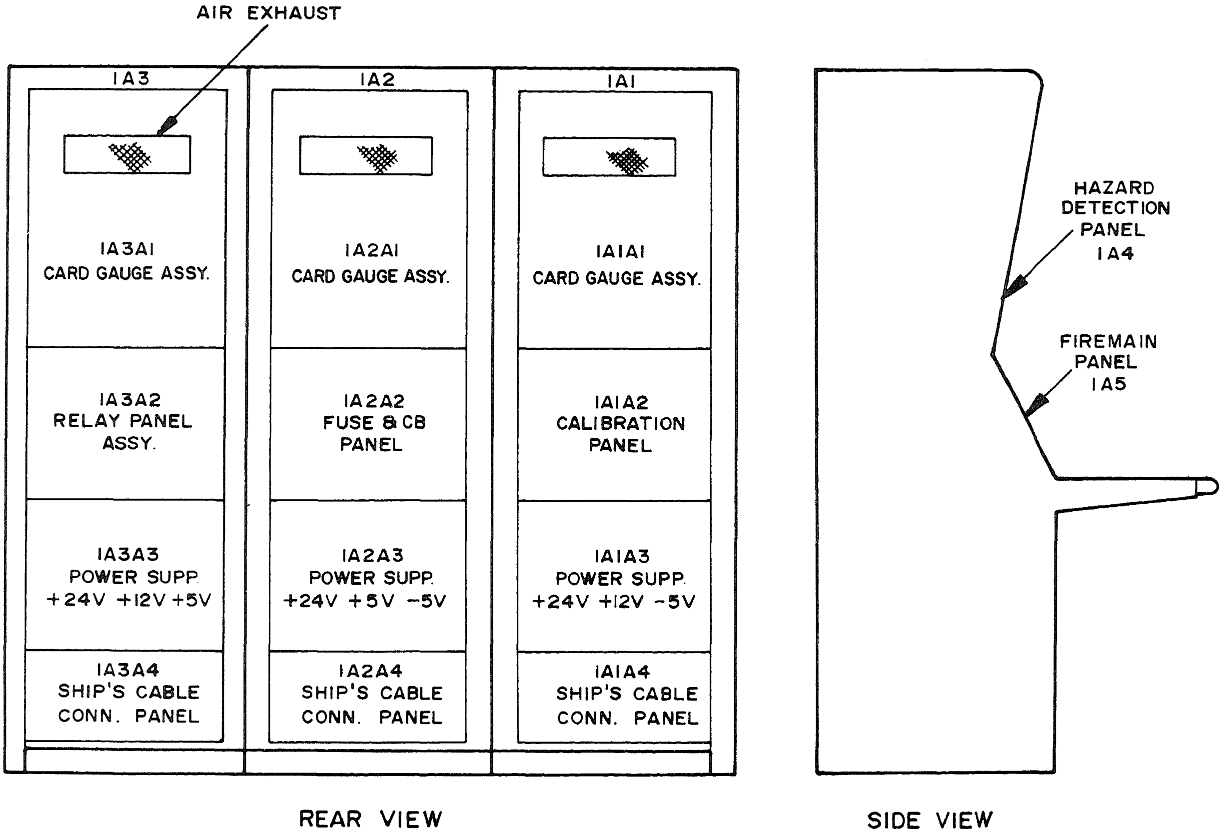

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Figure 9-46.—Damage control console component location.

Because of the redundant power supplies, console operation is unaffected if one supply for a particular voltage level should fail. If one supply of that group should fail, the remaining supply/supplies automatically assume(s) the load. Isolating diodes prevent the failed supply from absorbing current. The LED for the failed supply will go out, indicating that the supply has stopped supplying voltage. At the same time, the POWER SUPPLY FAIL light on the firemain panel illuminates. This shows that one of the nine power supplies is out of tolerance. The back panel of each power supply drawer contains the LEDs and a.c. fuses for each power supply and the drawer blower fuses.

Card Cages

Sections 1A3A1, 1A2A1, and 1A1A1 house the three card cage assemblies with the 155 PCBs used in monitoring, alarm, and control functions. One tab of each card is used to form a series circuit through all card receptacles in all three cages and the meter circuit card. Should this circuit be disturbed (card removed), the meter circuit board will illuminate the CARD REMOVED indicator on the firemain panel.

Fuse and Circuit Breaker Panel

Section 1A2A2 of the DCC has the fuse and CB panel. This panel contains the fuses to protect the console's 120-volt a.c. control circuits used for fire pump control and vent fan control. This panel also has the 24-volt d.c. fuses supplying the hazard detection and firemain panels. The main power CB supplying 120 volts a.c. to the console and the three power supply drawer switches are also on this panel.

Calibrate Panel

Section 1A1A2 has the DCC calibrate panel. This panel contains the pushbuttons and potentiometers necessary to set alarm points for low loop and low riser pressure circuits and to set full scale on both firemain panel pressure meters. It also has fuses for loop and riser pressure transducer circuits.

The LP alarm points for loop and riser circuits are set by depressing the PUSH TO SET ALARM POINT pushbutton and LOW PRESSURE/METER pushbutton at the same time for a particular point. The LOOP AND RISER PRESSURE meter will read directly the alarm set point. By adjusting the associated ADJUST potentiometer on the calibrate panel, you can set the alarm point to the desired value. Releasing the two pushbuttons returns the circuit to the normal condition.

Depressing the PUSH TO SET FULL SCALE pushbutton for either the loop and riser or pump discharge meters will send a full scale signal to the meter. You can then make the adjustment to the meter by using the mechanical full scale adjust on the meter body.

Relay Panel Assembly

Section 1A3A2 contains the relay panel. On the front of this panel are seven lighted pushbuttons. Pushbuttons S-2 through S-7 are used in testing the automatic fire pump control circuits for pumps 1 through 6. A satisfactory test of a circuit is shown by illumination of the pushbutton after it is depressed. Pushbutton S-1, LAMP TEST, is used to test the lights on this group of pushbuttons.

On the rear of the panel are nine relays used for automatic starting of fire pumps, summary fire alarms, and to inhibit start-up of fire pumps during circuit tests. Associated with each relay is a suppression diode for circuit protection.

Operator's Panels

The upper operator's panel (1A4) is designated the hazard detection panel. The lower operator's panel (1A5) is designated the firemain control panel. Both panels are shown in a foldout at the end of this chapter (figure 9-47).

The hazard detection panel has all the indicators for the fire, smoke, temperature, and bilge hazard alarm circuits. Also provided are pushbutton indicators to begin panel tests and to acknowledge alarms. The only control functions

of this panel are vent fan shutdown and summary fire alarm manual initiation.

The firemain control panel has the indicators and controls used to monitor the performance and status of the fire pumps, firemain risers, and firemain loops. Both automatic and manual starting of fire pumps is done from this panel. Also, the 1000 gpm aqueous film forming foam (AFFF) hangar sprinkler system is controlled from this panel. Included are pushbutton indicators for the start of panel fault, hazard, and lamp tests. This panel has a console status section to display certain abnormal conditions in the console.

CIRCUIT FUNCTIONAL DESCRIPTION

The following paragraphs describe major basic functions of the monitor and control circuits that support the hazard detection panel and firemain control panel. The electronic components that accomplish these functions are on the PCBs housed in the card cages.

Hazard Detection Circuits

All the alarm circuits associated with the hazard detection panel provide monitoring for both fault and hazard conditions. A typical hazard detection circuit has a sensor or group of sensors, a fault and hazard alarm card, a panel-mounted pushbutton indicator, inputs from the oscillator, and alarm status outputs to the audible, summary and alarm driver circuit card. Figure 9-48 shows a simplified hazard detection circuit.

The sensor circuits provide current signals to the fault and hazard alarm card. A sensor circuit may consist of a single sensor or up to five sensors in parallel. Four types of devices are used for fire and smoke detection.

1. Thermostatic Switches—These switches will change state when a specific temperature is reached. Three models are used in the system, providing alarm points of 105 °F, 125 °F, and 150 °F. Application of these switches has been selected considering the normal environment of the associated compartment. Typically, the 105 °F switches are used in magazines and other spaces where ammunition or critical propellants are stored. The 125 °F switches are used for flammable liquid storerooms, paint mixing and issue rooms, spaces for compressed gas storage, aviation storerooms, and other spaces with flammable liquids. The 150 °F switches are used for miscellaneous storerooms and lockers.

2. Fixed Temperature and Rate of Rise Detectors—These sensors change state at a specific temperature (105 °F, 125 °F, or 150 °F) or if the rate of temperature increase exceeds 15 °F per minute. These sensors are used in certain non-critical storage spaces. Specific sensors were selected considering the normal environment of the space.

3. Ionization Detectors—These detectors sample the environment or products of combustion. An ionization detector will typically change state at 40-percent Dioctylphthalate Aerosol concentration (about 2- to 3-percent smoke). Ionization detectors are installed in crew living areas and all ship electronic spaces not provided with Ⓦ ventilation. Direct sampling ionization detectors are installed in Ⓦ ducts serving ship electronic spaces and crew living areas.

4. Manual Pull Stations—In addition to the temperature and smoke detectors, nine manual pull stations are provided. They allow remote activation of a fire alarm. Pull stations are located in main engineering spaces, selected passageways, and at the helicopter hangar door.

Each sensor circuit ends in an end-of-line resistor. This establishes a normal condition current flow in the sensor line. Should any sensor in the line detect a hazardous condition and change state, the current in the sensor line will increase to an alarm level. If the sensor circuit opens at any time, the current in the circuit will drop below the normal value, indicating a fault in the circuit.

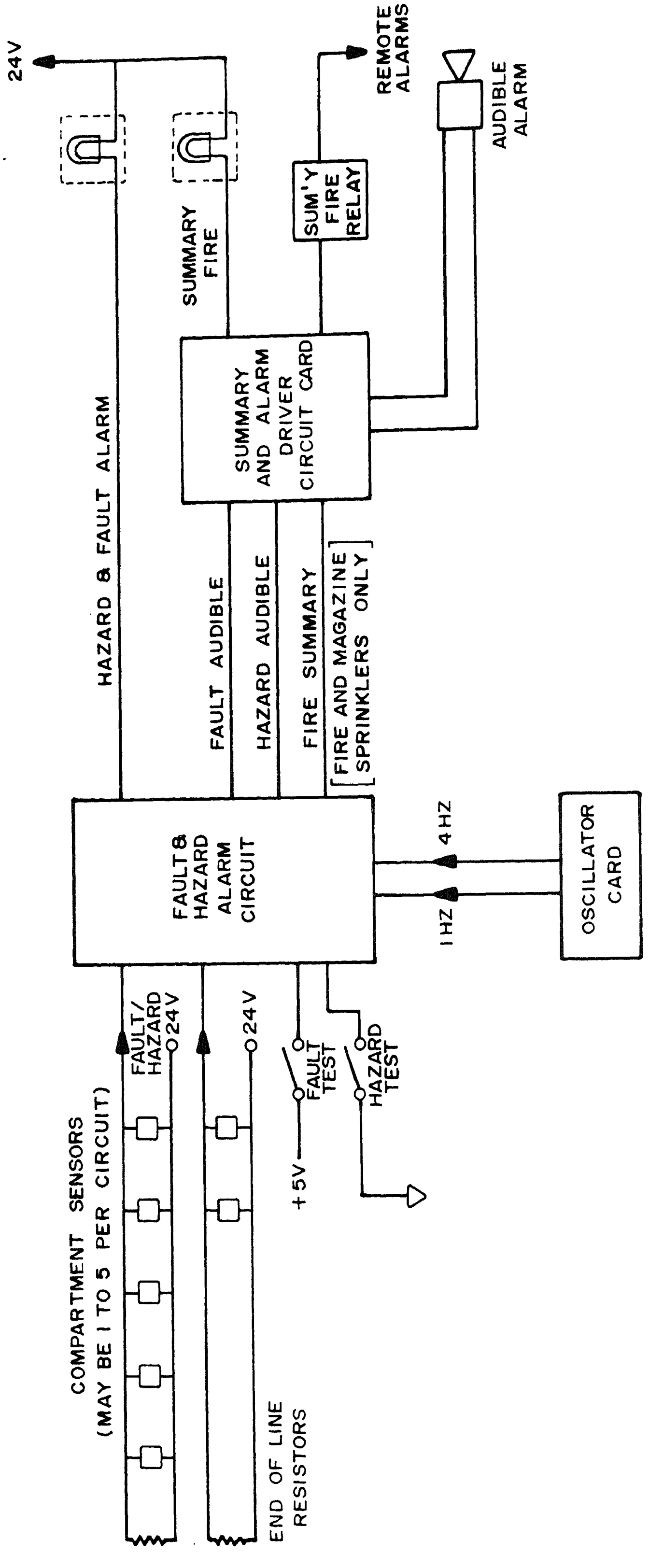

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Figure 9-48.—Typical DCC hazard detection circuit.

Table 9-6.—Sensor Input Loop, Normal and Alarm Circuit Levels

SENSOR	NON-ALARM CONDITION	HAZARD ALARM STATE	FAULT ALARM STATE
Fire, thermal and manual pull station only	13.5 mA ±2 mA	60 mA (min.) 71 mA (max.)	less than 8 mA
Thermal, rate-of-rise, and smoke only	13.5 mA ±2 mA	30 mA +10 mA − 3 mA	less than 8 mA
All others	2 mA ±0.5 mA	5 mA ±1 mA	less than 0.5 mA

Table 9-6 gives the sensor input loop current values for different circuit conditions. Sensor loops that detect fire conditions operate with higher current values than do other types of loop.

The sensor circuit current is sent through a fault and hazard alarm card. Each of these cards has two comparator circuits to accommodate two sensor circuits. Each comparator has provisions to accept either a high-current or low-current sensor circuit.

If the current in the sensor loop exceeds the preset alarm threshold, the fault and hazard alarm card will begin a hazard alarm output. This causes the associated indicator light to flash at a 4-Hz rate. The audible, summary and alarm driver card will sound the audible alarm at the same 4-Hz rate. When the fault and hazard alarm card receives an acknowledge signal, it will remove the signal to the audible, summary and alarm driver card. This silences the audible alarm (if no additional alarms exist). At the same time, the signal to the indicator light goes to a steady state. The circuit remains in this condition until the current in the sensor circuit drops below the alarm threshold. At this time, the indicator light goes out.

If the sensor line current drops below the fault alarm threshold, the fault and hazard alarm card starts a fault alarm. The fault alarm has the audible alarm pulsed at a 1-Hz rate and the associated indicator flashing at a 1-Hz rate. When the fault and hazard alarm card receives an acknowledge signal in response to a fault alarm, it removes the audible alarm signal. This indicator remains flashing, however, until the sensor line current goes above the fault alarm threshold.

The hazard detection circuits are provided with hazard and fault test functions. Pushbutton indicators on the hazard detection panel show these tests. If one of the HAZARD ALARM TEST pushbuttons is depressed, a common hazard test signal is sent to the fault and hazard alarm cards for that section of the panel. This signal will cause each comparator to latch into the alarm state. The 4-Hz visual and audible alarms are energized. Depressing the ALARM ACK pushbutton (with HAZARD ALARM TEST held depressed) tests the acknowledge functions. This will silence the audible alarm and steady all indicators. Releasing the HAZARD ALARM TEST pushbutton and depressing the ALARM TEST and the ALARM ACK pushbuttons will reset the circuits to the normal state. The summary fire relay is disabled during this test. This prevents activation of the remote summary fire alarms.

Depressing a FAULT ALARM TEST pushbutton indicator applies a 5-volt fault test signal to the fault and hazard alarm card associated with that portion of the panel. This causes each comparator to go into the fault alarm state. Then a 1-Hz audible alarm and all associated indicators will flash at the 1-Hz rate. Acknowledging this test alarm (while holding FAULT ALARM TEST depressed) silences the audible only. Releasing the FAULT ALARM TEST pushbutton ends the test and restores the circuits to normal operation.

The hazard detection panel is divided into two sections for these tests with corresponding pushbuttons for each. The dividing line is about frame 280. This division is made to prevent

overloading of the circuits by having all indicators on at one time. The two pushbuttons are electrically interlocked. This prevents simultaneous testing of both halves.

Summary Fire Circuit

The summary fire alarm circuit shows a fire somewhere in the ship. The basic components of this circuit include the audible, summary and alarm driver card, a SUMMARY FIRE ALARM pushbutton indicator, a summary fire alarm relay (K9), and remote alarms at each quarterdeck and on the bridge.

As shown in figure 9-48, hazard detection circuits associated with fire detection and magazine sprinkle activation input a fire summary signal to the audible, summary and alarm driver card. If any alarm signal exists on these inputs, the driver card energizes the summary alarm relay and illuminates the SUMMARY FIRE ALARM light on the hazard detection panel. The summary alarm relay activates the alarm mechanism at the three remote locations. These remote alarms must be silenced at the remote location. The summary fire relay remains energized as long as the hazard detection circuit is in an alarm state.

In addition to the hazard detection circuit inputs, the audible, summary and alarm driver card receives an input from the SUMMARY FIRE ALARM pushbutton indicator. When this button is depressed, the summary fire relay is energized and the panel indicator illuminated. This allows the DCC operator to start a summary fire alarm for a fire condition not detected by a hazard detection circuit.

Vent Fan Shutdown Control

Each of the four zones on the hazard detection panel has VENT FAN SHUTDOWN CONTROL pushbutton indicators. They are associated with the Ⓦ and Z ventilation systems. They provide ON/OFF status for the vent systems for each zone. They enable the DCC operator to shut down selected systems.

Zone 1 (frame 28 to 138) has a Ⓦ pushbutton indicator. When this is depressed, a 120-volt a.c. off signal is sent to a vent shutdown relay in load center (LC) 11. The relay then latches in the OFF state. This causes the shunt trip coil to open both the normal and alternate CBs feeding the power panel that supplies the vent fans for this zone. The Ⓦ ventilation for zone 1 will be secured. There is no ON vent fan control at the DCC. To restore the system to normal operation, you must depress the VENT RESET pushbutton at LC 11. This changes the vent shutdown relay to the ON state. You must close the normal and alternate supply CBs and restart each vent fan at its motor control station. The sequence for zones 2, 3, and 4 is the same, except that multiple shutdown relays and feeder breakers may be involved.

Firemain System Pressure Monitoring

The firemain system pressure is monitored at 15 points. The nine loop and riser monitoring circuits use a common LOOP AND RISER PRESSURE 0 to 200 psig panel meter to display pressures from selected points. This common meter also provides hazard alarming for LP conditions. The six fire pump discharge circuits use a common PUMP DISCHARGE PRESSURE 0 to 200 psig panel meter to display pressures from selected points.

The pressure transducers used at these 15 points are similar to the type used in the FO fill and transfer system. These transducers have their own signal conditioning circuits. They cause a 4- to 20-mA signal to flow that is proportional to pressure.

A simplified loop and riser pressure monitoring circuit is shown in figure 9-49. The 4- to 20-mA pressure signal is routed through its meter selector pushbutton to a fixed resistor (R2) and returns to -5 volts. If the selector pushbutton for this transducer is depressed, the level signal will be sent through the LOOP AND RISER PRESSURE meter. The pressure level will be displayed. The selector pushbutton has holding coils that latch the selected circuit to the meter once the pushbutton has been depressed. The holding coil circuits are interlocked so that depressing one selector pushbutton will open the other holding circuits. Therefore, once a selector pushbutton has been depressed, that pressure parameter will be displayed continuously until another point is selected. Additionally, the interlocking prevents more than one point being selected at once. The selector pushbutton energizes the light on its indicator. This indicates which

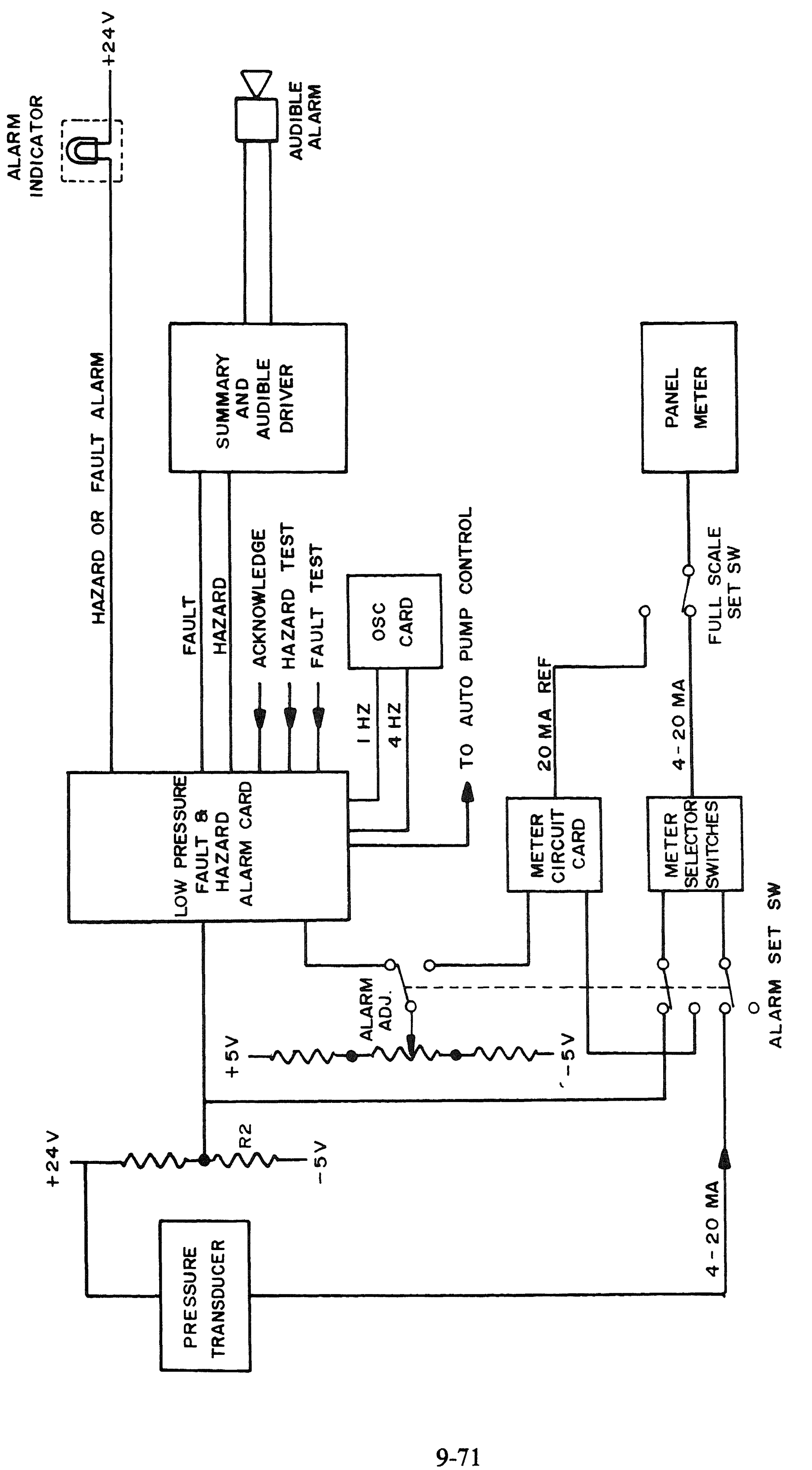

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Figure 9-49.—Simplified pressure monitor circuit.

pressure is being displayed. The LP fault and hazard alarm card receives a voltage signal proportional to pressure. This signal is compared to the alarm reference. If the pressure signal drops below the alarm reference, the LP fault and hazard card will start a hazard alarm. The LOW PRESSURE indicator on the firemain panel will flash at a 4-Hz rate. A hazard alarm signal will be sent to the audible, summary and alarm driver. This will sound the audible alarm at the 4-Hz rate. When the fault and hazard alarm card receives an acknowledge signal, the hazard output to the audible, summary and alarm driver will be removed. This silences the audible alarm. The flashing indicator will go steady. When the pressure signal goes above the alarm reference, the fault and hazard circuit will return to normal. The indicator light will extinguish.

Fault alarm initiation is also provided by this circuit. If current drops to zero in the pressure transducer circuit, the fault and hazard alarm card detects a loss of voltage across the sensing resistor (R2). A fault alarm will be initiated. The indicator will flash at a 1-Hz rate. At the same time, a fault alarm signal will be sent to the audible, summary and alarm driver. This will sound the audible alarm at a 1-Hz rate. When the LP fault and hazard card receives an acknowledge signal, the output to the audible, summary and alarm driver is removed. The audible alarm will stop. This will not affect the flashing indicator. The fault circuit does not latch. It will return to normal whenever the transducer circuit current is restored.

The firemain control panel has a HAZARD ALARM TEST and a FAULT ALARM TEST pushbutton indicator. These function similar to the hazard detection panel hazard and fault tests. They simulate hazard and fault conditions in the LP fault and hazard cards.

You can adjust LP alarm points by using the PUSH TO SET ALARM POINT and ADJUST functions of the calibrate panel. When the PUSH TO SET ALARM POINT pushbutton is depressed, the alarm reference signal is removed from the LP fault and hazard card and routed to the meter circuit card. If the meter selector pushbutton has been depressed, the meter will read the alarm point for that circuit. You can then adjust the ADJUST potentiometer to obtain the desired alarm point. Releasing the pushbutton will return the circuit to normal operation. You can set alarm points from 20 to 150 psig.

The calibrate panel is also used in calibrating full scale reading for the LOOP AND RISER PRESSURE meter. When this PUSH TO ADJUST FULL SCALE pushbutton is depressed, a 20-mA reference signal from the meter circuit card is routed to the meter. Adjustment of the meter reading is done using the mechanical full scale adjustment on the meter. Releasing the pushbutton returns the meter to normal operation.

Fire pump discharge pressure monitoring circuits do not have fault and hazard detection functions. The 4- to 20-mA pressure signal from the transducers is routed to the meter selector pushbutton and to the PUMP DISCHARGE PRESSURE meter if the pushbutton is depressed. Selector pushbutton interlocking is similar to the loop and riser circuit. Only one point can be selected at a time. That point will be displayed continuously until another pushbutton is depressed. The PUMP DISCHARGE PRESSURE meter full scale reading is established similar to the LOOP AND RISER PRESSURE meter.

Fire Pump Control

The firemain panel provides monitoring and remote control of the six fire pumps. The pump discharge pressures are displayed on a common PUMP DISCHARGE PRESSURE meter. Pump ON/OFF status is displayed by individual pushbutton indicators for each pump. Manual and automatic modes of pump control are available at the panel. Figure 9-50 shows a simplified fire pump control diagram.

MANUAL CONTROL.—Manual control is by 12 (2 for each pump) momentary action pushbutton indicators. The ON and OFF pushbuttons supply 120-volt a.c. to the ON and OFF relays in the pump controllers for starting and stopping the pumps. Auxiliary contacts at the controllers are fed back to illuminate the ON and OFF indicators.

AUTO CONTROL.—Auto control is done by logic in the DCC. The components of this circuit are the auto pump driver card and the relays in the relay panel. The auto pump logic card

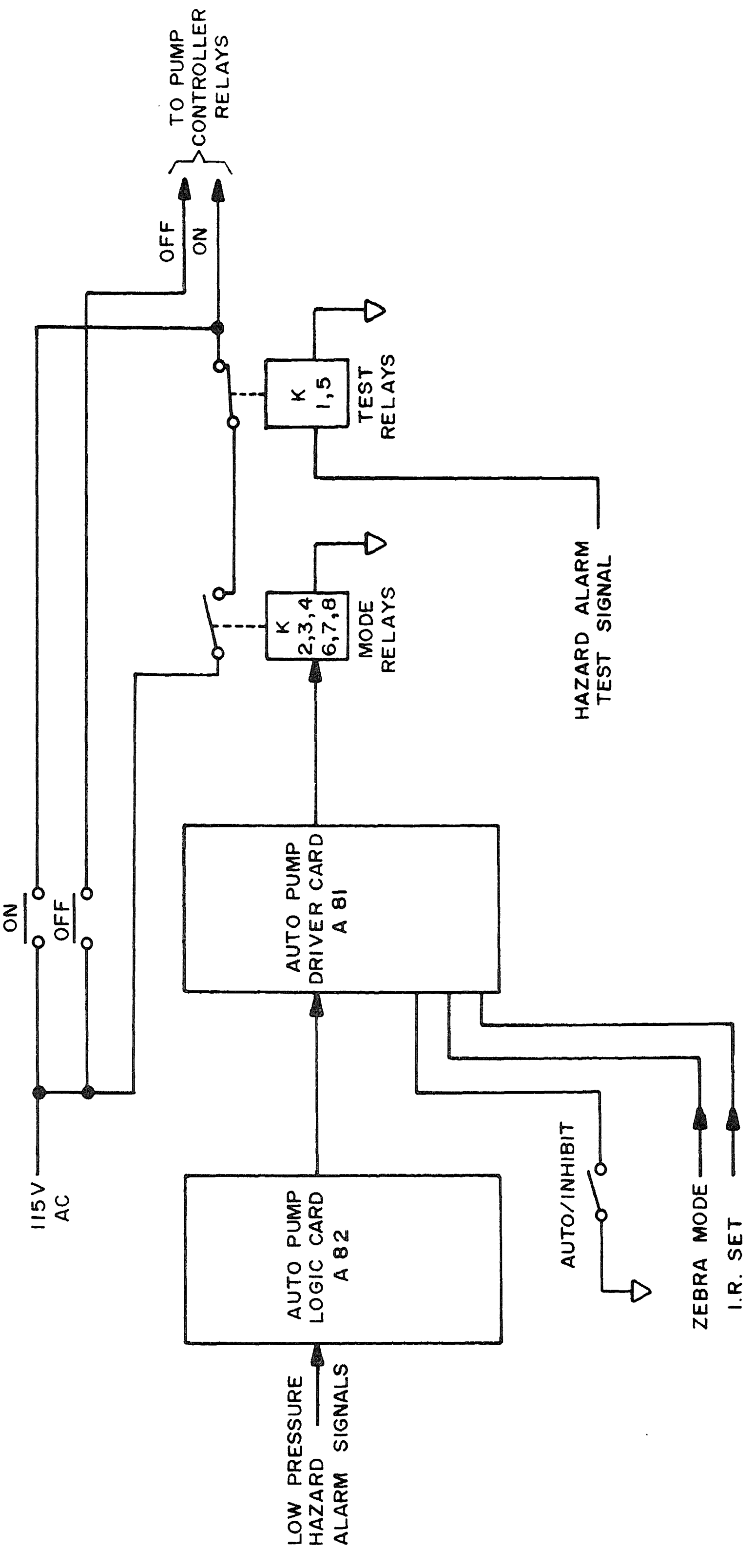

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Figure 9-50.—Simplified DCC fire pump control diagram.

responds to inputs from the six riser LP hazard alarm circuits. Outputs from the logic card energize a relay driver in the auto pump driver card. This, in turn, energizes the required relay. It supplies 120 volts a.c. to the ON relay at the pump controller to start a pump. Auto control mode for a particular pump is in effect only when the associated AUTO/INHIBIT selector is in the AUTO position. The auto control logic provides four operating modes discussed in the following paragraphs.

NORMAL MODE.—A riser LP alarm starts the auto control (after a 0.5-second time delay to eliminate response to transients). At the end of this time delay, the lowest numbered alarmed riser fire pump is started, if not inhibited or already running. After a 1- to 5-second delay (adjustable), the next highest numbered pump, whose riser LP alarm is on, starts. This procedure continues in sequence until no alarms remain. Auto pump control then resets.

ZEBRA MODE (SEGREGATED LOOP).—Zebra mode is established when all four Zebra mode pushbutton indicators are in the CLOSE position. Auto control operation is then as in normal mode except the 1- to 5-second time delay is eliminated. This allows simultaneous starting of additional pumps if required.

IR SET MODE (UNSEGREGATED LOOPS).—When auto control receives an IR set signal, it sequentially scans through the pumps and turns on two available (not inhibited and not already running) pumps. If a scan through the six pumps does not result in two additional pumps being turned on, the circuit resets. Operating is then returned to the normal mode.

IR SET MODE (SEGREGATED LOOPS).—When auto control sees an IR set signal, it turns on fire pumps No. 3 and No. 4 if not already on or inhibited. Auto control then returns to Zebra mode.

You can test auto control at the relay panel. You can use pushbutton indicators on the panel to simulate riser LP alarm conditions for each pump's auto control circuit. When the pushbutton is depressed, its indicator illuminates if the circuit responds satisfactorily. You can depress two or more pushbuttons simultaneously to check for proper time delays. Actual starting of the pump is inhibited during these tests.

Valve Status Monitoring

The firemain panel provides OPEN/CLOSE status monitoring for the six fire pump inlet and six fire pump discharge valves. The status of the indicator lights is controlled by limit switches on the valves.

There are OPEN/CLOSE pushbutton indicators for the firemain loop segregation valves. One is for each of the four Zebra valves. There are no valve limit switches associated with these indicators. The console operator must set their state. The pushbuttons are the latching type. They change state each time they are depressed. When all four indicators are in the CLOSE state, a Zebra mode signal is sent to the auto control circuit to modify pump logic.

Aqueous Film Forming Foam Control and Monitoring

The AFFF control and monitoring functions available from the firemain panel are as follows.

1. AFFF FP-180 system monitoring
2. 1000 gpm AFFF proportioner control and monitoring
3. AFFF hangar sprinkler control and monitoring

The AFFF FP-180 system monitoring circuits provide status of AFFF FP-180 system activation. There are four indicators on the firemain panel to indicate the operational status of the four AFFF FP-180 systems. The indicating lamps are controlled by limit switches on the individual FP-180 control valves. The lamps are illuminated (AFFF FP-180 ON) when the respective AFFF FP-180 system is activated.

Control and status of the hangar AFFF sprinkler system and the 1000 gpm AFFF proportioner is provided at the firemain panel by four indicator switches. Activation of the 1000 GPM AFFF PROP ON or OFF switches supplies 120 volts a.c. to the hangar AFFF proportioner controller for starting or stopping of the proportioner. Auxiliary contacts within the proportioner

controller are hardwired to indicating lamps on the DCC to provide proportioner ON/OFF status. Control of the hangar AFFF sprinkler valve is similar to that of the AFFF proportioner. The SPRG ON or OFF switches supply 120 volts a.c. to the valve controller to open or close the sprinkler valve. Contacts within the controller are hardwired to indicating lamps to provide SPRG ON/OFF status at the DCC.

Chemical, Biological, Radiation (CBR) Monitoring

The fireman panel has four indicators to provide ON status for each of the four CBR washdown groups. Each indicator is wired to a remote group relay which closes upon activation of the associated CBR washdown group. When the relay is closed, the respective panel indicator illuminates. No control of the washdown group is available at the DCC.

Infrared Suppression System Monitoring

Two indicator lights on the firemain control panel provide status of the IR suppression system. The IR SET indicator illuminates when an IR command has been started at either the bridge or the CIC. The IR ON indicator illuminates when one or more of the seven IR system valves open. The signals that control these indicators originate at the PACC. The IR set signal is also used to modify auto control logic.

Console Status Monitoring

The firemain control panel has a console status section to warn of abnormal conditions within the DCC itself. The monitored conditions are power supply failure, hazard oscillator failure, fault oscillator failure, console high temperature, and card removed.

POWER SUPPLY FAILURE CIRCUIT.—The power supply fail circuit monitors the output voltage level of each d.c. power supply at its power supply drawer. Each monitored voltage is sent to the meter circuit card. When any of these voltages drops below its limit, the meter circuit card will illuminate the POWER SUPPLY FAILURE indicator. To find out which supply has failed, the operator must observe the individual power supply indicator lights at each power supply drawer.

HAZARD AND FAULT OSCILLATOR FAIL CIRCUITS.—The hazard and fault oscillator card supplies both the 4-Hz and the 1-Hz rates for hazard and fault alarms. There are two oscillators circuits on the card for each rate. One is designated main and the other designated spare. Normally, the main oscillators are supplying the console. If one of the main oscillators fails, its spare will automatically take over. The oscillator card will then cause the associated oscillator fail indicator to illuminate. Console operation is unaffected, but you should replace the oscillator card.

CONSOLE HIGH TEMPERATURE MONITORING.—In each of the three cabinet assemblies of the DCC is a preset temperature switch. If the temperature at any one of these temperature switches exceeds 168 °F, the CONSOLE HIGH TEMP indicator will illuminate.

CARD REMOVED MONITORING.—Each printed circuit card in the DCC has one pin connected to an adjacent pin. These pins are all connected in series through the receptacles. This series circuit inputs to the meter circuit card. If the series circuit is interrupted by a removed or improperly seated card, the meter circuit will cause the CARD REMOVED indicator to illuminate.

CONSOLE OPERATION

This section is limited to general procedures for DCC power application, turnoff, and self-tests. Detailed instructions for starting, operating, and receiving this equipment are contained in NAVSEA 0988-138-4010.

Power Application

The DCC is energized from the fuse and CB panel. The three power supply panel switches (S1, S2, and S3) should be in the ON position. Placing the MAIN POWER CB (CB1) in the ON position will then energize the DCC. All power supply indicator lights should be on. Since

application of power to the console may cause some circuits to alarm, all flashing pushbutton indicators should be depressed to reset the alarm circuitry.

Self-Tests

The hazard detection panel and the firemain panel are equipped with alarm and lamp tests. There are HAZARD ALARM and FAULT ALARM TEST pushbuttons for each half of the hazard detection panel and for the firemain panel. Exercise each group independently. Momentarily depressing a HAZARD ALARM TEST switch causes all hazard indicators for that group to flash. The audible alarm will sound at 4-Hz rate. While holding the HAZARD ALARM TEST pushbutton depressed, depressing the ALARM ACK for the panel causes all flashing lights to go steady and silences the audible alarm. Then you may release the HAZARD ALARM TEST. Depressing ALARM ACK again extinguishes all indicators not actually in alarm and restores the circuits to normal operation.

Momentarily depressing a FAULT ALARM TEST switch causes all hazard indicators for that group to flash at a 1-Hz rate. The audible alarm will then sound at a 1-Hz rate. While holding FAULT ALARM TEST depressed, depressing the ALARM ACK for the panel causes the audible alarm to silence (indicators remain flashing). You may then release FAULT ALARM TEST. Depressing ALARM ACK again extinguishes all indicators not actually in alarm and restores the circuits to normal operation.

After all fault and hazard tests have been performed, use the LAMP TEST to check all indicator lights not tested during the alarm tests. Perform these tests upon energizing the console and at regular intervals during operation.

Normal Securing

The DCC is secured by placing the MAIN POWER CB in the OFF position.

SUMMARY

While this chapter was written to familiarize you with the operation of the consoles in the CCS of the DD-963 class ships, it is not enough information for operational or troubleshooting purposes. This material is provided to give you, a junior GSE, enough knowledge to begin qualifying on CCS watches, using the PQS applicable to the watch station you are learning.

The knowledge gained by reading this chapter should also give you enough information to assist a qualified technician in the repair of this important equipment. Only technical manuals can give you the in-depth procedures as to how to troubleshoot and repair the CCS equipment. Never try to work on this equipment without the proper manuals. The proposed *GSE 1 & C* rate training manual will also provide more information on the troubleshooting techniques and repair procedures.

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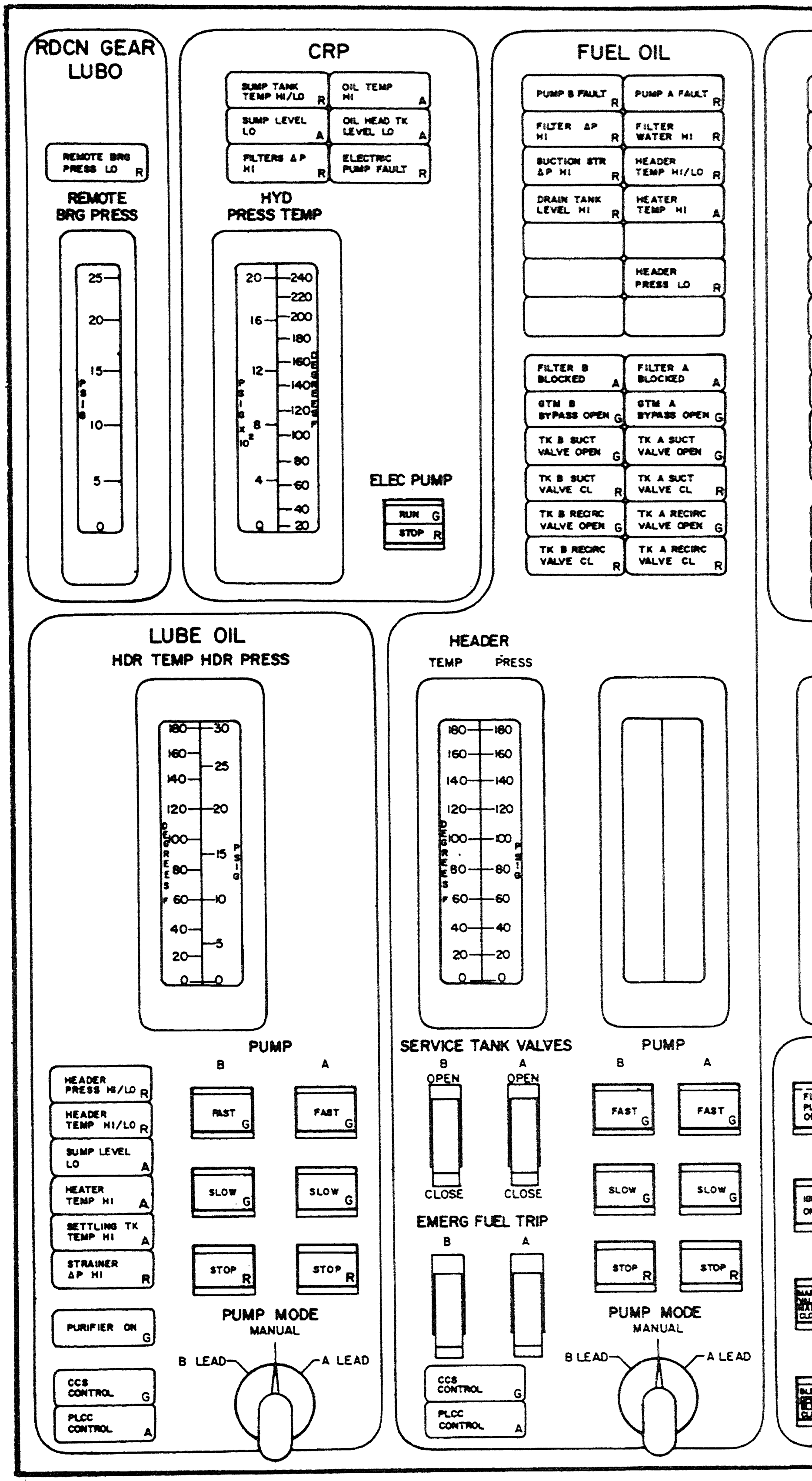
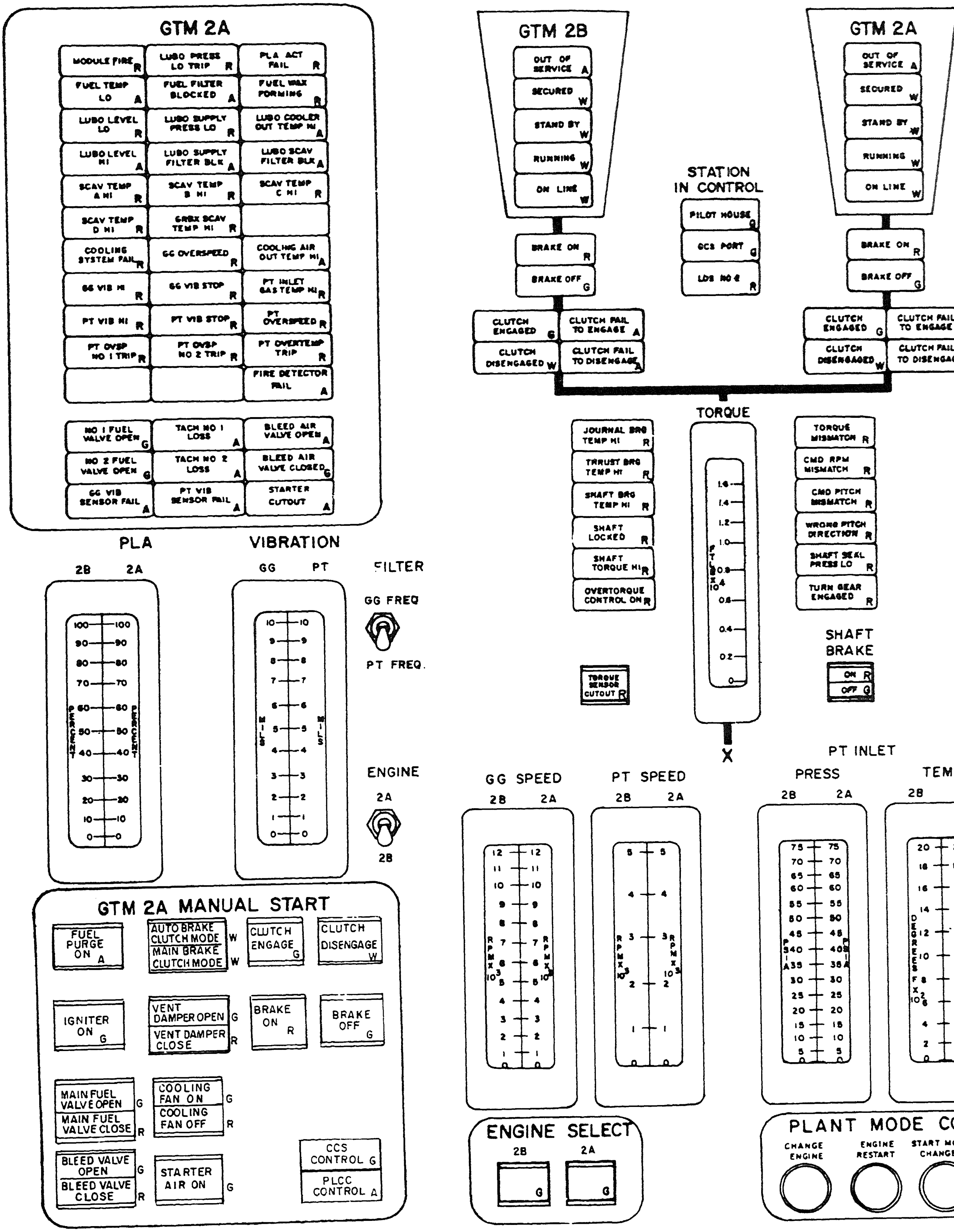
Marine Gas Turbine Operations, NAVEDTRA 10097, Naval Education and Training Program Development Center, Pensacola, Fla., 1981.

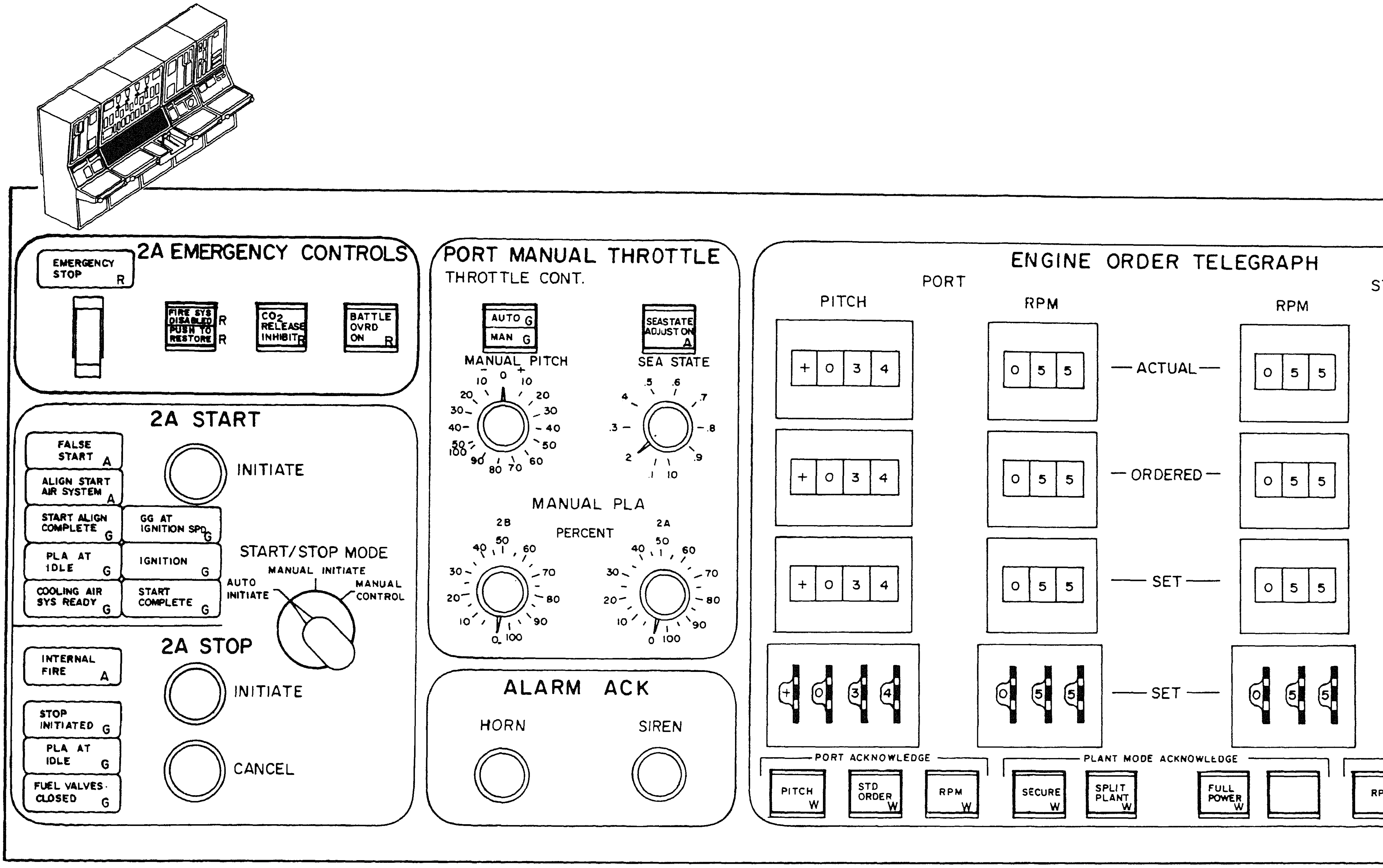
Propulsion and Auxiliary Machinery Control Equipment (PAMCE), Volume 1, S9234-BW-MMO-010. Naval Sea Systems Command, Washington, D.C., 1 January 1982.

Propulsion and Auxiliary Machinery Information System Equipment (PAMISE), Volume 1, S9234-BV-MMO-010. Naval Sea Systems Command, Washington, D.C., 1 January 1982.

Propulsion Plant Manual, Propulsion Plant System for DD-963 Class Ships, Volume 4, S9234-AL-GTP-040/DD-963 PPM. Naval Sea Systems Command, Washington, D.C., 1 May 1980.


RDCN GEAR LUBO
REMOTE BRG PRESS LO R
REMOTE BRG PRESS
PSIG
CRP
SUMP TANK TEMP HI/LO R
OIL TEMP HI A
SUMP LEVEL LO A
OIL HEAD TK LEVEL LO A
FILTERS ΔP HI R
ELECTRIC PUMP FAULT R
HYD PRESS TEMP
ELEC PUMP
RUN G
STOP R
FUEL OIL
PUMP B FAULT R
PUMP A FAULT R
FILTER ΔP HI R
FILTER WATER HI R
SUCTION STR ΔP HI R
HEADER TEMP HI/LO R
DRAIN TANK LEVEL HI R
HEATER TEMP HI A
HEADER PRESS LO R
FILTER B BLOCKED A
FILTER A BLOCKED A
GTM B BYPASS OPEN G
GTM A BYPASS OPEN G
TK B SUCT VALVE OPEN G
TK A SUCT VALVE OPEN G
TK B SUCT VALVE CL R
TK A SUCT VALVE CL R
TK B RECIRC VALVE OPEN G
TK A RECIRC VALVE OPEN G
TK B RECIRC VALVE CL R
TK A RECIRC VALVE CL R
LUBE OIL
HDR TEMP HDR PRESS
DEGREES F
PSIG
HEADER PRESS HI/LO R
HEADER TEMP HI/LO R
SUMP LEVEL LO A
HEATER TEMP HI A
SETTLING TK TEMP HI A
STRAINER ΔP HI R
PURIFIER ON G
CCS CONTROL G
PLCC CONTROL A
PUMP
B
A
FAST G
SLOW G
STOP R
PUMP MODE
MANUAL
B LEAD
A LEAD
HEADER
TEMP
PRESS
SERVICE TANK VALVES
OPEN
CLOSE
EMERG FUEL TRIP


GTM 2A
MODULE FIRE R
LUBO PRESS LO TRIP R
PLA ACT FAIL R
FUEL TEMP LO A
FUEL FILTER BLOCKED A
FUEL WAX FORMING R
LUBO LEVEL LO R
LUBO SUPPLY PRESS LO R
LUBO COOLER OUT TEMP HI A
LUBO LEVEL HI A
LUBO SUPPLY FILTER BLK A
LUBO SCAV FILTER BLK A
SCAV TEMP A HI R
SCAV TEMP B HI R
SCAV TEMP C HI R
SCAV TEMP D HI R
GRBX SCAV TEMP HI R
COOLING SYSTEM FAIL R
GG OVERSPEED R
COOLING AIR OUT TEMP HI A
GG VIB HI R
GG VIB STOP R
PT INLET GAS TEMP HI R
PT VIB HI R
PT VIB STOP R
PT OVERSPEED R
PT OVSP NO 1 TRIP R
PT OVSP NO 2 TRIP R
PT OVERTEMP TRIP R
FIRE DETECTOR FAIL A
NO 1 FUEL VALVE OPEN G
TACH NO 1 LOSS A
BLEED AIR VALVE OPEN A
NO 2 FUEL VALVE OPEN G
TACH NO 2 LOSS A
BLEED AIR VALVE CLOSED G
GG VIB SENSOR FAIL A
PT VIB SENSOR FAIL A
STARTER CUTOUT A
GTM 2B
OUT OF SERVICE A
SECURED W
STAND BY W
RUNNING W
ON LINE W
BRAKE ON R
BRAKE OFF G
CLUTCH ENGAGED G
CLUTCH FAIL TO ENGAGE A
CLUTCH DISENGAGED W
CLUTCH FAIL TO DISENGAGE A
STATION IN CONTROL
PILOT HOUSE G
CCS PORT G
LOS NO 2 R
GTM 2A
OUT OF SERVICE A
SECURED W
STAND BY W
RUNNING W
ON LINE W
BRAKE ON R
BRAKE OFF G
CLUTCH ENGAGED G
CLUTCH FAIL TO ENGAGE
CLUTCH DISENGAGED W
CLUTCH FAIL TO DISENGAGE
TORQUE
JOURNAL BRG TEMP HI R
THRUST BRG TEMP HI R
SHAFT BRG TEMP HI R
SHAFT LOCKED R
SHAFT TORQUE HI R
OVERTORQUE CONTROL ON R
TORQUE SENSOR CUTOUT R
FT LBS X 10^4
1.6 1.4 1.2 1.0 0.8 0.6 0.4 0.2 0
X
TORQUE MISMATCH R
CMD RPM MISMATCH R
CMD PITCH MISMATCH R
WRONG PITCH DIRECTION R
SHAFT SEAL PRESS LO R
TURN GEAR ENGAGED R
SHAFT BRAKE
ON R
OFF G
PLA
2B 2A
PERCENT
100 90 80 70 60 50 40 30 20 10 0
VIBRATION
GG PT
MILS
10 9 8 7 6 5 4 3 2 1 0
FILTER
GG FREQ
PT FREQ.
ENGINE
2A
2B
GTM 2A MANUAL START
FUEL PURGE ON A
AUTO BRAKE CLUTCH MODE W
MAIN BRAKE CLUTCH MODE W
CLUTCH ENGAGE G
CLUTCH DISENGAGE W
IGNITER ON G
VENT DAMPER OPEN G
VENT DAMPER CLOSE R
BRAKE ON R
BRAKE OFF G
MAIN FUEL VALVE OPEN G
MAIN FUEL VALVE CLOSE R
COOLING FAN ON G
COOLING FAN OFF R
BLEED VALVE OPEN G
BLEED VALVE CLOSE R
STARTER AIR ON G
CCS CONTROL G
PLCC CONTROL A
GG SPEED
2B 2A
RPM X 10^3
12 11 10 9 8 7 6 5 4 3 2 1 0
PT SPEED
2B 2A
RPM X 10^3
5 4 3 2 1 0
PT INLET
PRESS
2B 2A
PSIA
75 70 65 60 55 50 45 40 35 30 25 20 15 10 5 0
TEM
2B
DEGREES F X 10^2
20 18 16 14 12 10 8 6 4 2 0
ENGINE SELECT
2B 2A
G G
PLANT MODE C
CHANGE ENGINE
ENGINE RESTART
START M CHANGE


2A EMERGENCY CONTROLS
EMERGENCY STOP R
FIRE SYS DISABLED PUSH TO RESTORE R R
CO2 RELEASE INHIBIT R
BATTLE OVRD ON R
2A START
FALSE START A
ALIGN START AIR SYSTEM A
START ALIGN COMPLETE G
GG AT IGNITION SPD G
PLA AT IDLE G
IGNITION G
COOLING AIR SYS READY G
START COMPLETE G
INITIATE
START/STOP MODE
AUTO INITIATE
MANUAL INITIATE
MANUAL CONTROL
2A STOP
INTERNAL FIRE A
STOP INITIATED G
PLA AT IDLE G
FUEL VALVES CLOSED G
INITIATE
CANCEL
PORT MANUAL THROTTLE
THROTTLE CONT.
AUTO G
MAN G
SEASTATE ADJUST ON A
MANUAL PITCH
SEA STATE
MANUAL PLA
PERCENT
2B
2A
ALARM ACK
HORN
SIREN
ENGINE ORDER TELEGRAPH
PORT
PITCH
RPM
RPM
ACTUAL
ORDERED
SET
SET
PORT ACKNOWLEDGE
PLANT MODE ACKNOWLEDGE
PITCH W
STD ORDER W
RPM W
SECURE W
SPLIT PLANT W
FULL POWER W

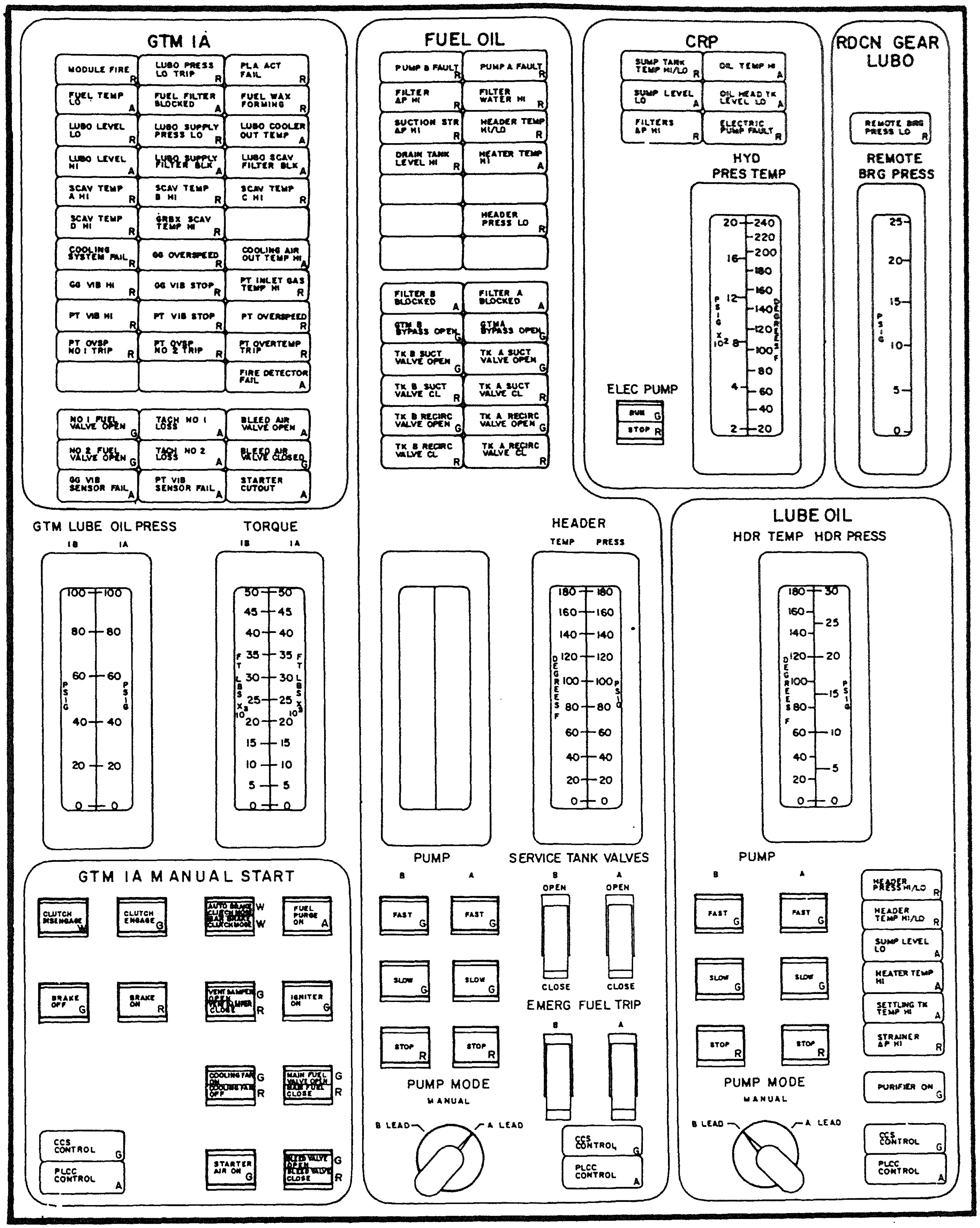


Figure 9-7.—PACC—engine No. 1 panel.

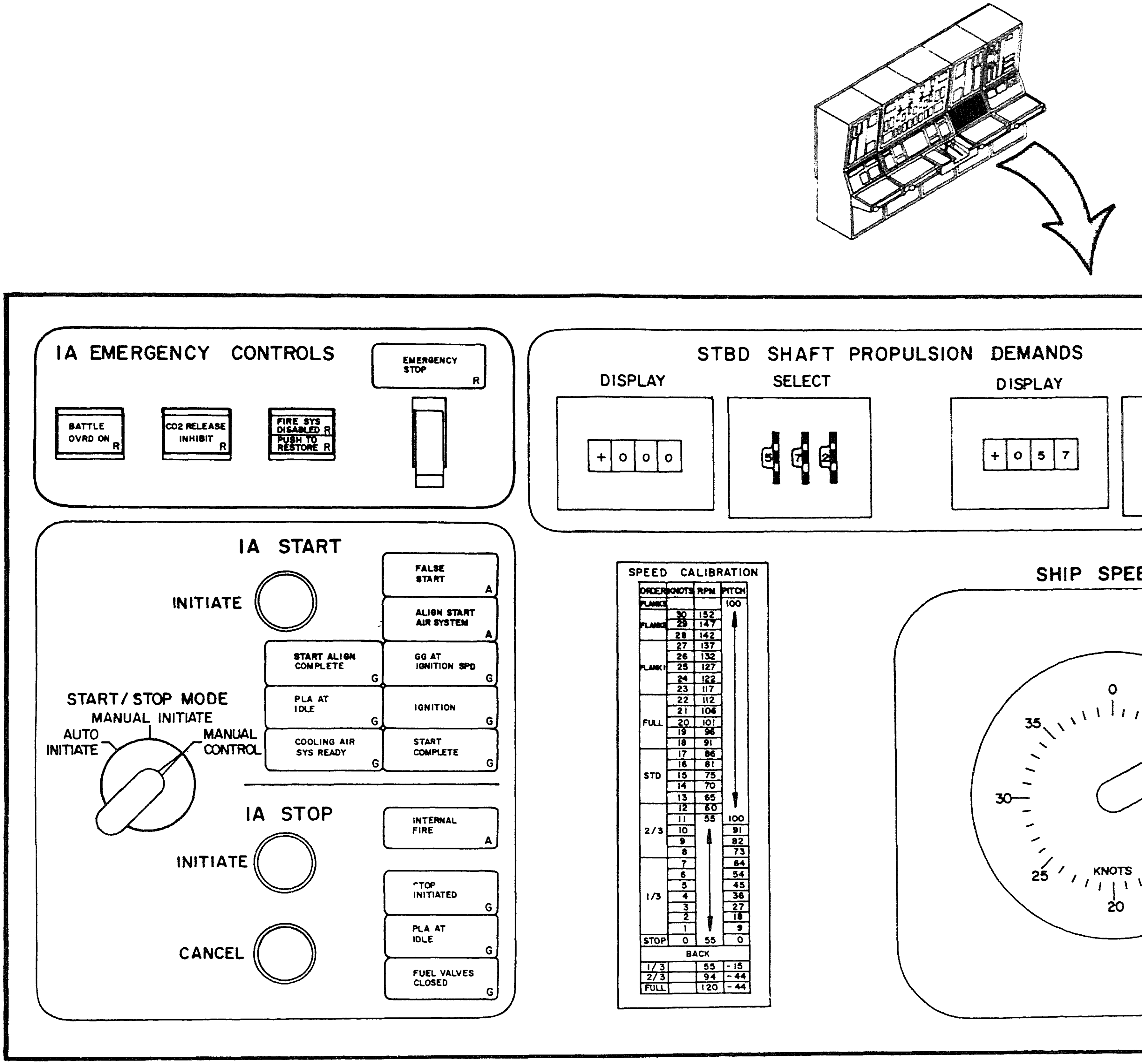


Figure 9-8.—PACC—engine No. 1 demands panel.

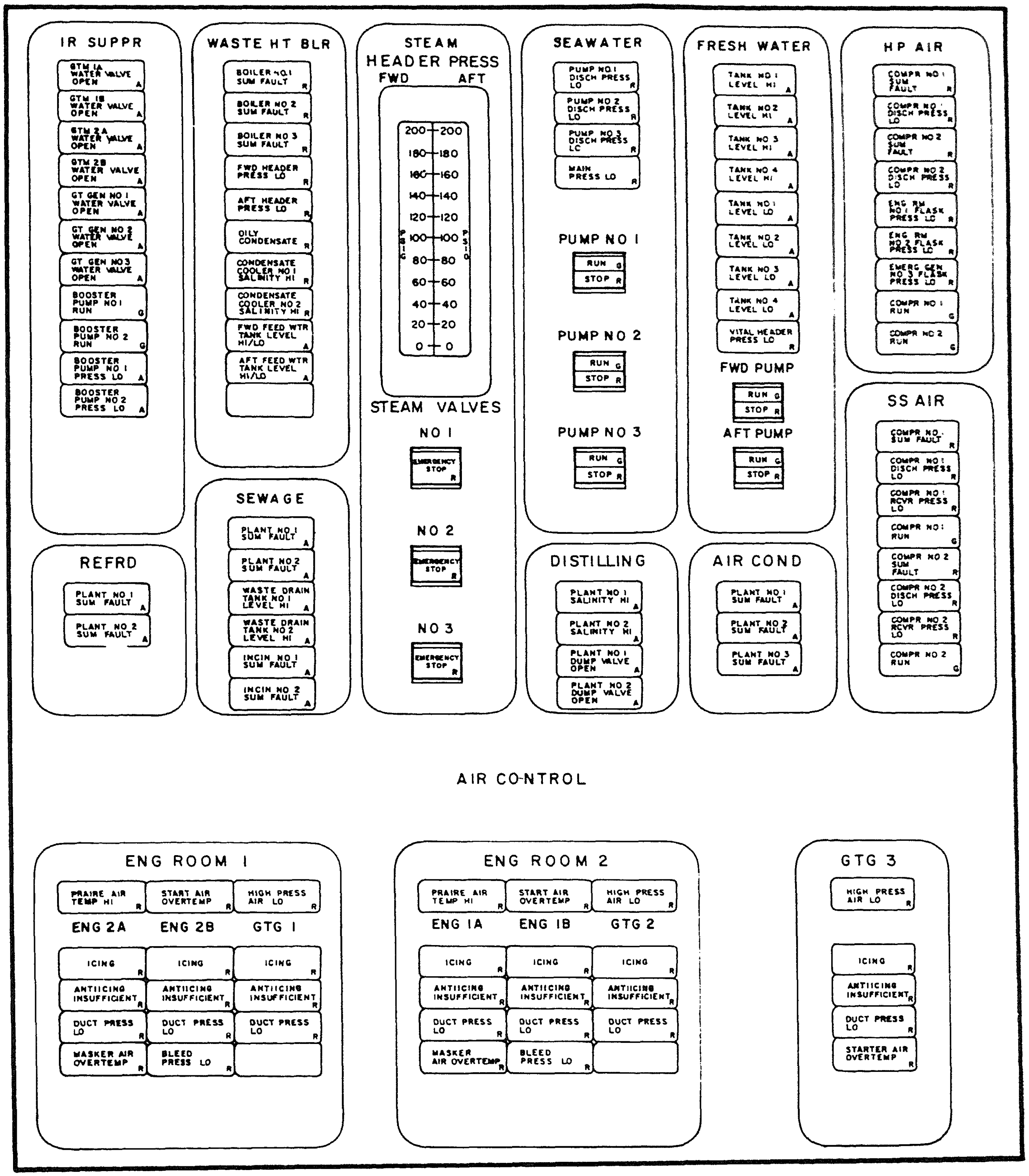


Figure 9-9.—PACC—auxiliary/bleed air panel

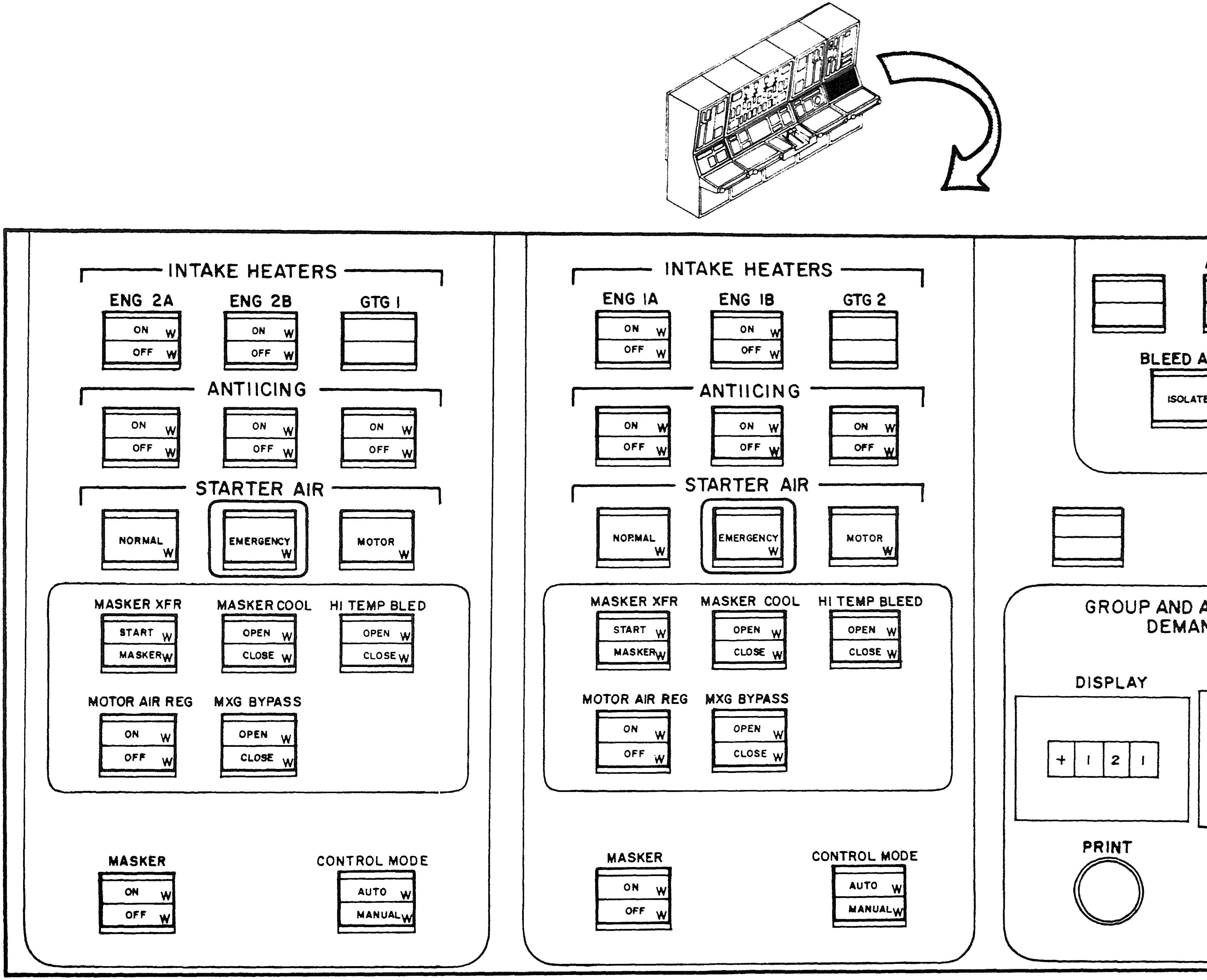
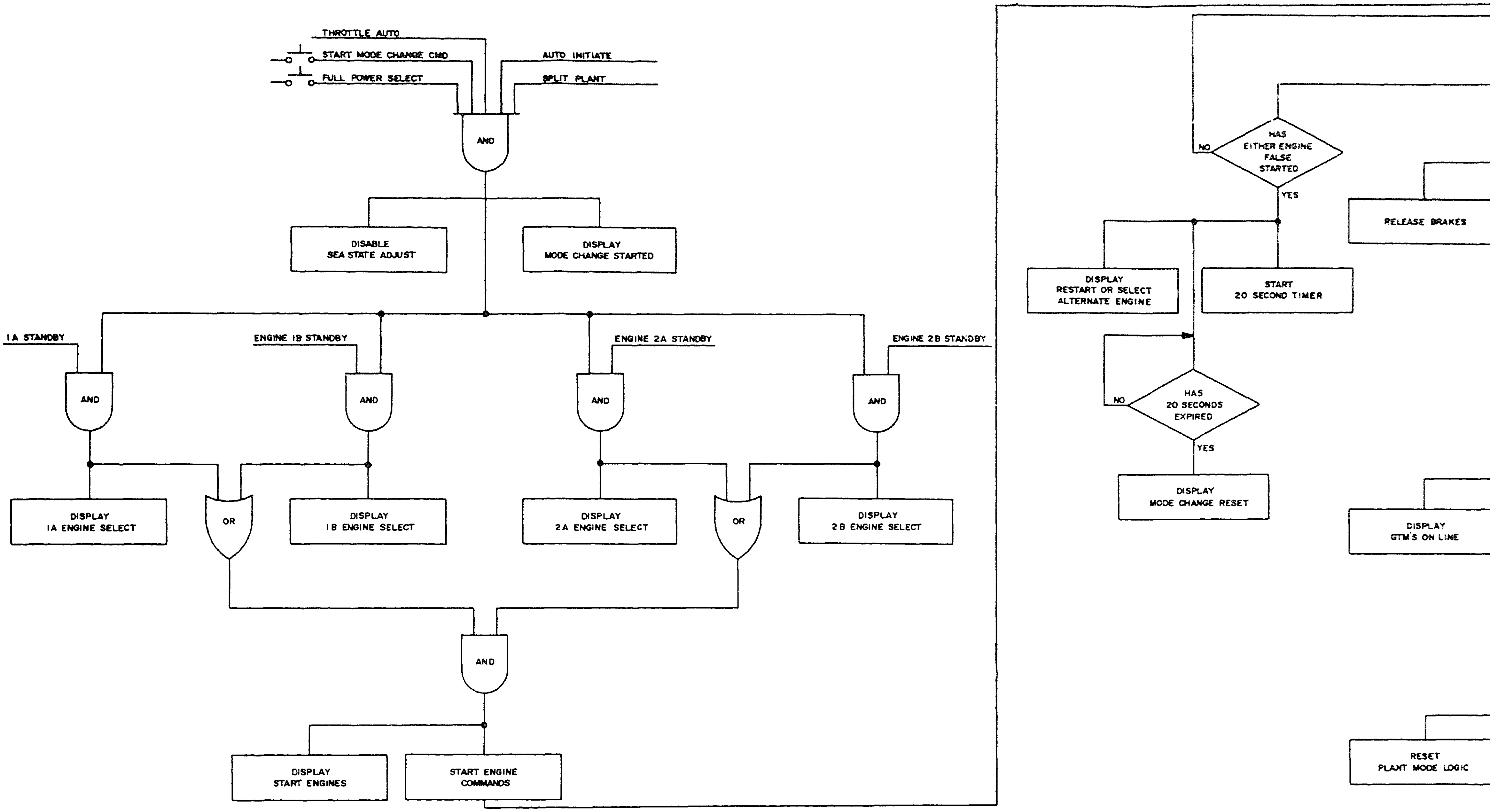


Figure 9-10.—PACC—bleed air control panel.


THROTTLE AUTO
START MODE CHANGE CMD
FULL POWER SELECT
AUTO INITIATE
SPLIT PLANT
AND
DISABLE SEA STATE ADJUST
DISPLAY MODE CHANGE STARTED
1A STANDBY
ENGINE 1B STANDBY
ENGINE 2A STANDBY
ENGINE 2B STANDBY
AND
AND
AND
AND
DISPLAY 1A ENGINE SELECT
OR
DISPLAY 1B ENGINE SELECT
DISPLAY 2A ENGINE SELECT
OR
DISPLAY 2B ENGINE SELECT
AND
DISPLAY START ENGINES
START ENGINE COMMANDS
HAS EITHER ENGINE FALSE STARTED
NO
YES
DISPLAY RESTART OR SELECT ALTERNATE ENGINE
START 20 SECOND TIMER
HAS 20 SECONDS EXPIRED
NO
YES
DISPLAY MODE CHANGE RESET
RELEASE BRAKES
DISPLAY GTM'S ON LINE
RESET PLANT MODE LOGIC

Figur

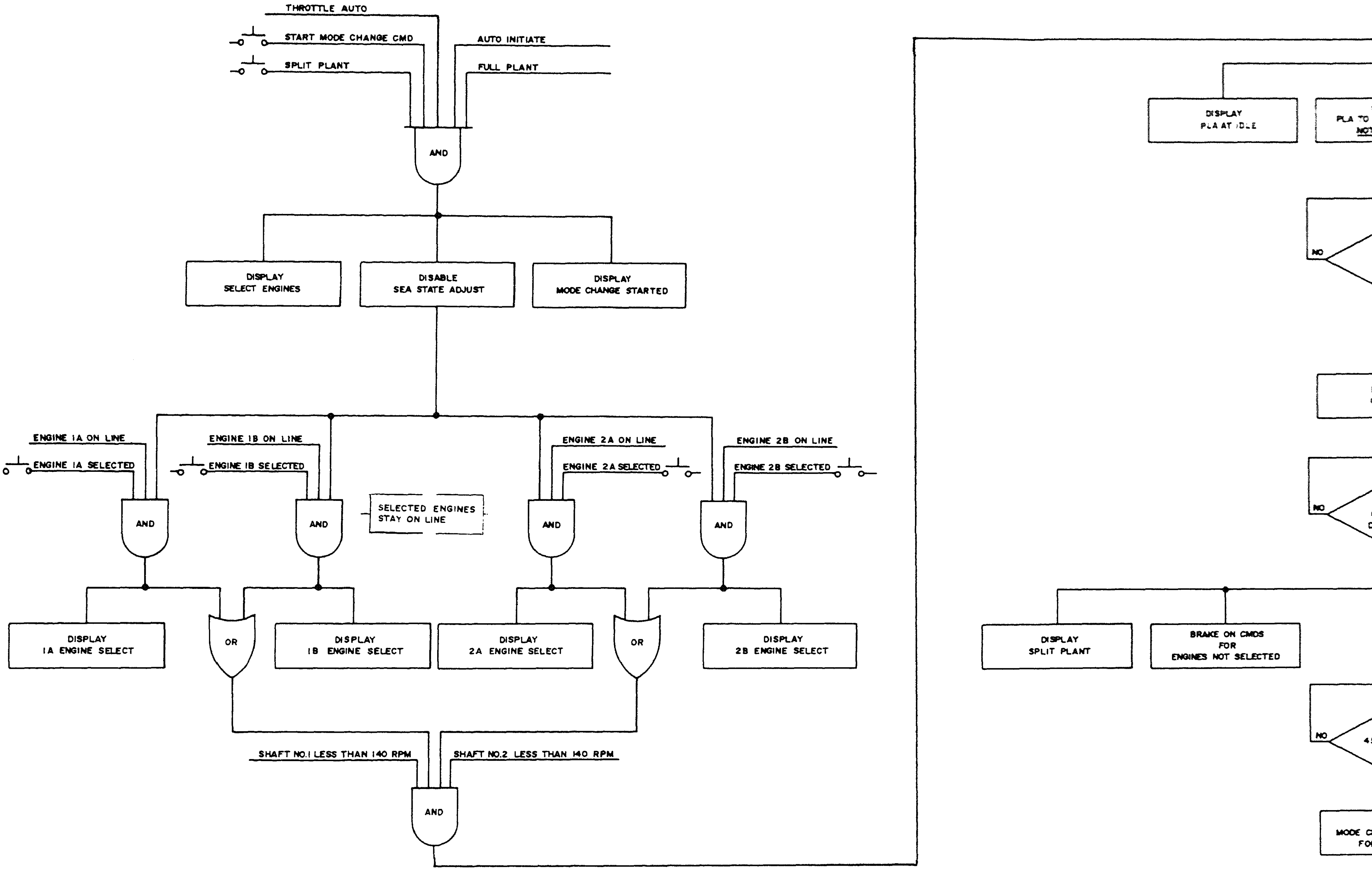
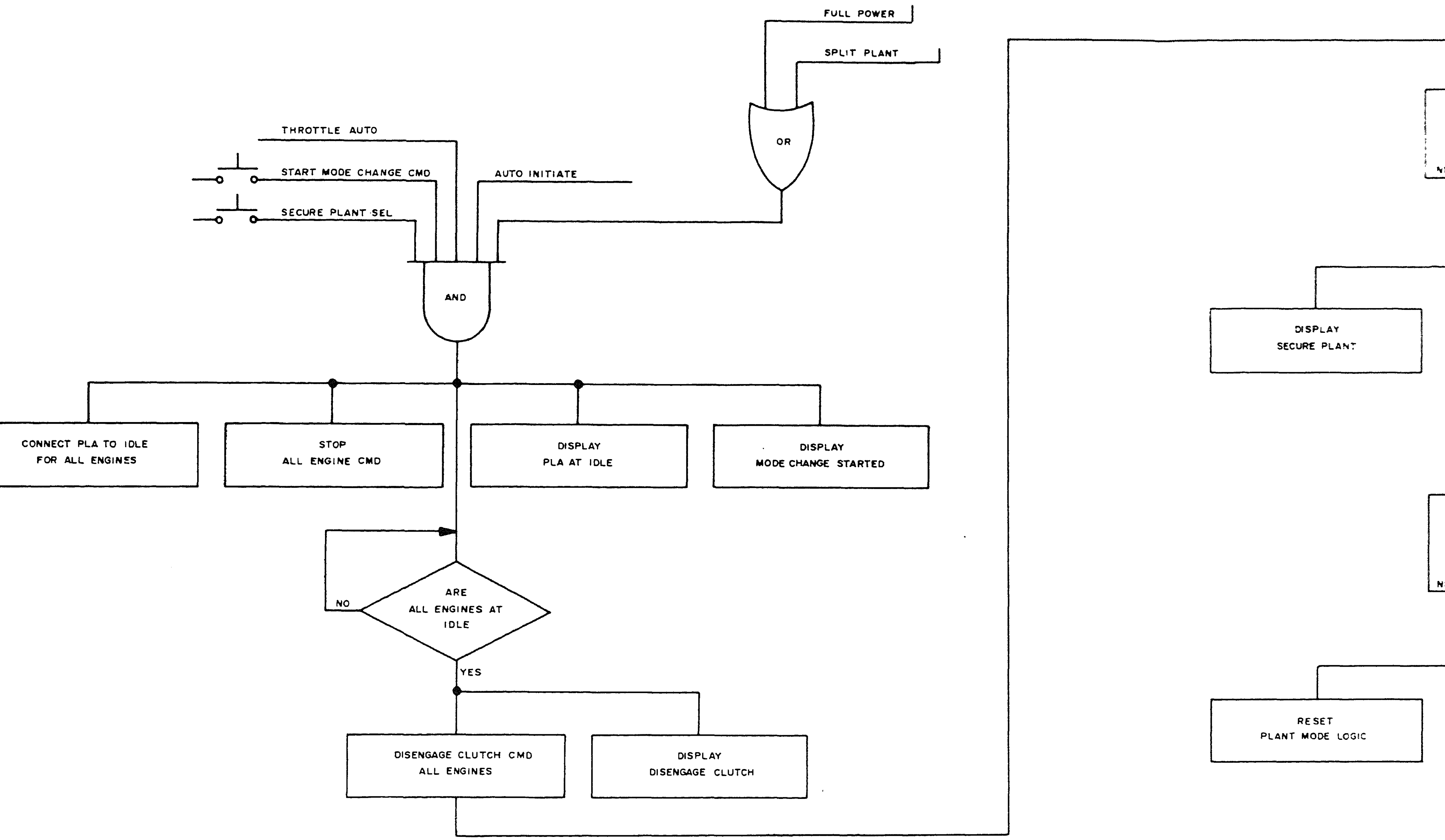

THROTTLE AUTO
START MODE CHANGE CMD
SPLIT PLANT
AUTO INITIATE
FULL PLANT
AND
DISPLAY SELECT ENGINES
DISABLE SEA STATE ADJUST
DISPLAY MODE CHANGE STARTED
ENGINE 1A ON LINE
ENGINE 1A SELECTED
ENGINE 1B ON LINE
ENGINE 1B SELECTED
SELECTED ENGINES STAY ON LINE
ENGINE 2A ON LINE
ENGINE 2A SELECTED
ENGINE 2B ON LINE
ENGINE 2B SELECTED
AND
AND
AND
AND
DISPLAY 1A ENGINE SELECT
OR
DISPLAY 1B ENGINE SELECT
DISPLAY 2A ENGINE SELECT
OR
DISPLAY 2B ENGINE SELECT
SHAFT NO.1 LESS THAN 140 RPM
SHAFT NO.2 LESS THAN 140 RPM
AND
DISPLAY PLA AT IDLE
NO
NO
DISPLAY SPLIT PLANT
BRAKE ON CMDS FOR ENGINES NOT SELECTED
NO

Figure 9-18.-



FULL POWER
SPLIT PLANT
OR
THROTTLE AUTO
START MODE CHANGE CMD
AUTO INITIATE
SECURE PLANT SEL
AND
CONNECT PLA TO IDLE FOR ALL ENGINES
STOP ALL ENGINE CMD
DISPLAY PLA AT IDLE
DISPLAY MODE CHANGE STARTED
NO
ARE ALL ENGINES AT IDLE
YES
DISENGAGE CLUTCH CMD ALL ENGINES
DISPLAY DISENGAGE CLUTCH
DISPLAY SECURE PLANT
RESET PLANT MODE LOGIC

Figure 9-20.—

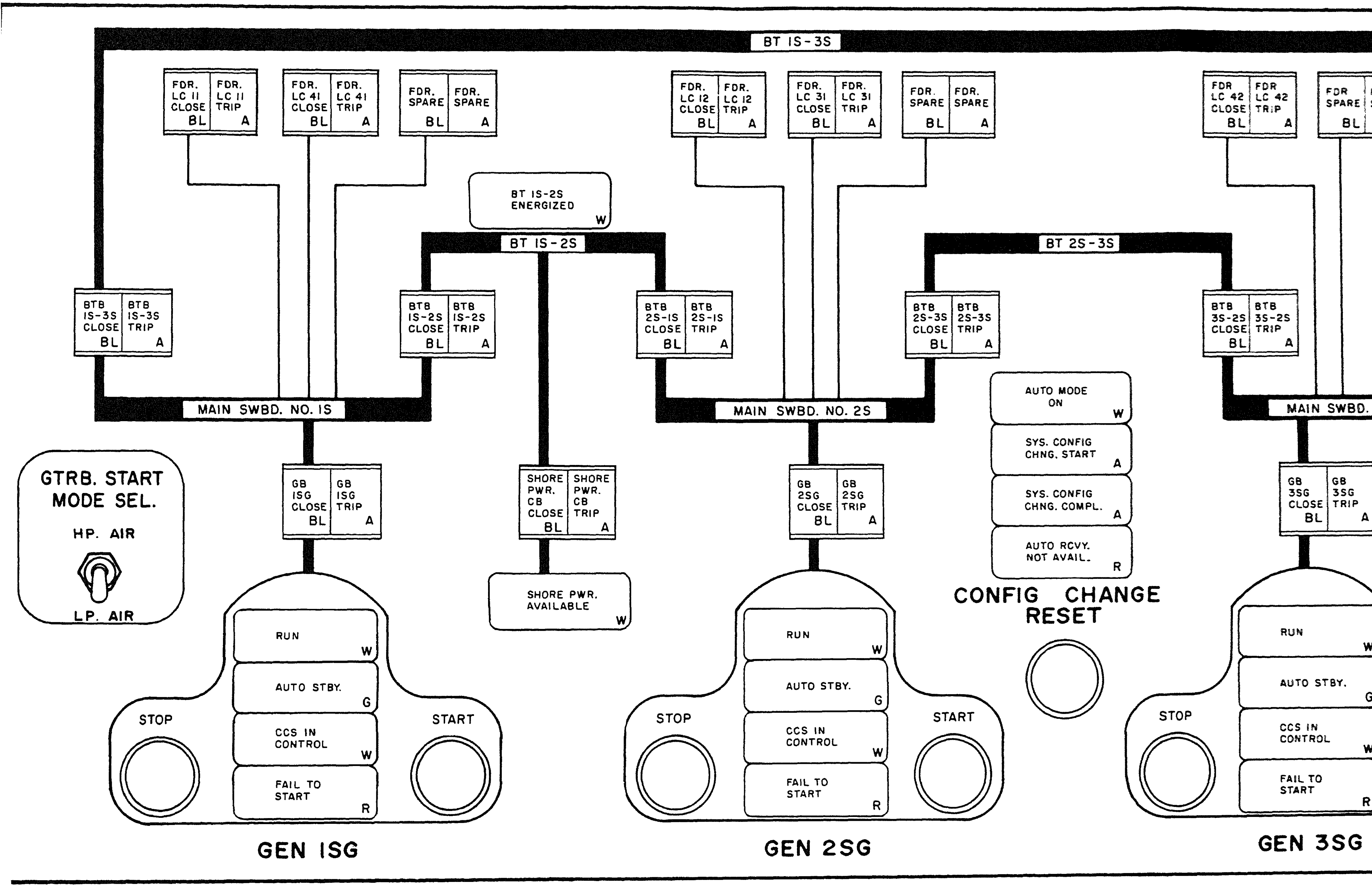


Figure 9-23.—EPCC—MIMIC panel.

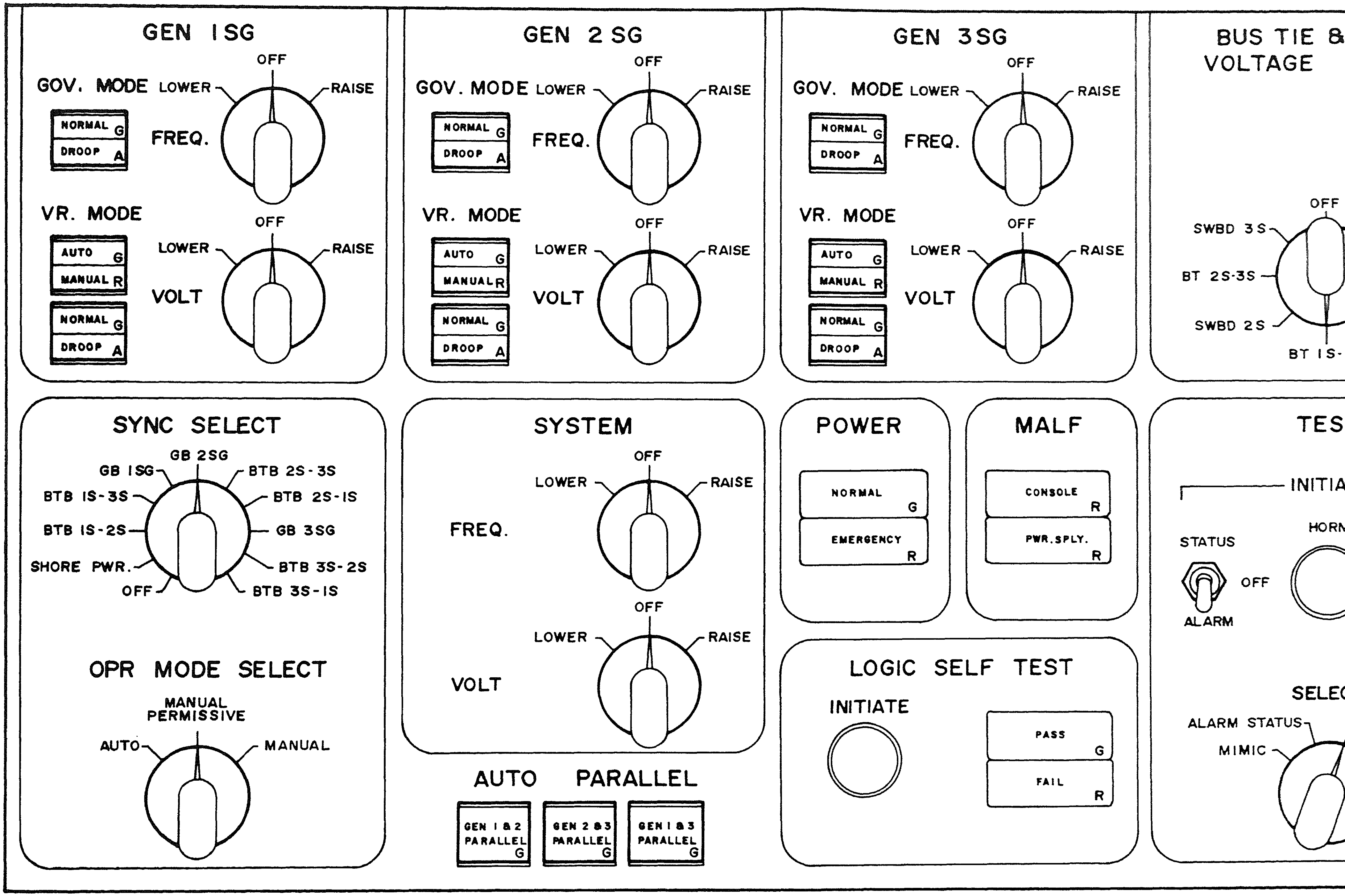


Figure 9-24.—EPCC—system control panel.

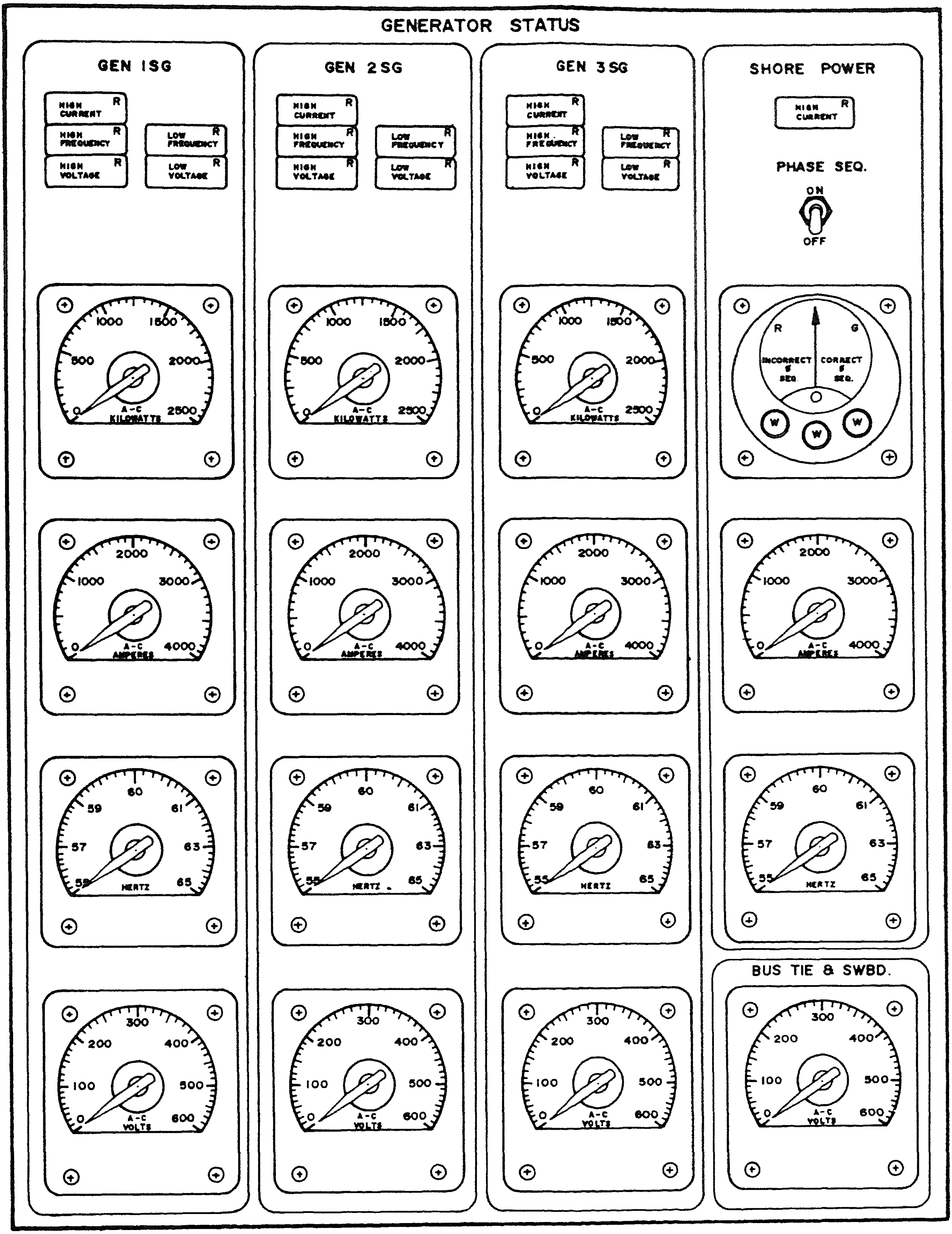


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Figure 9-25.—EPCC—generator status panel.

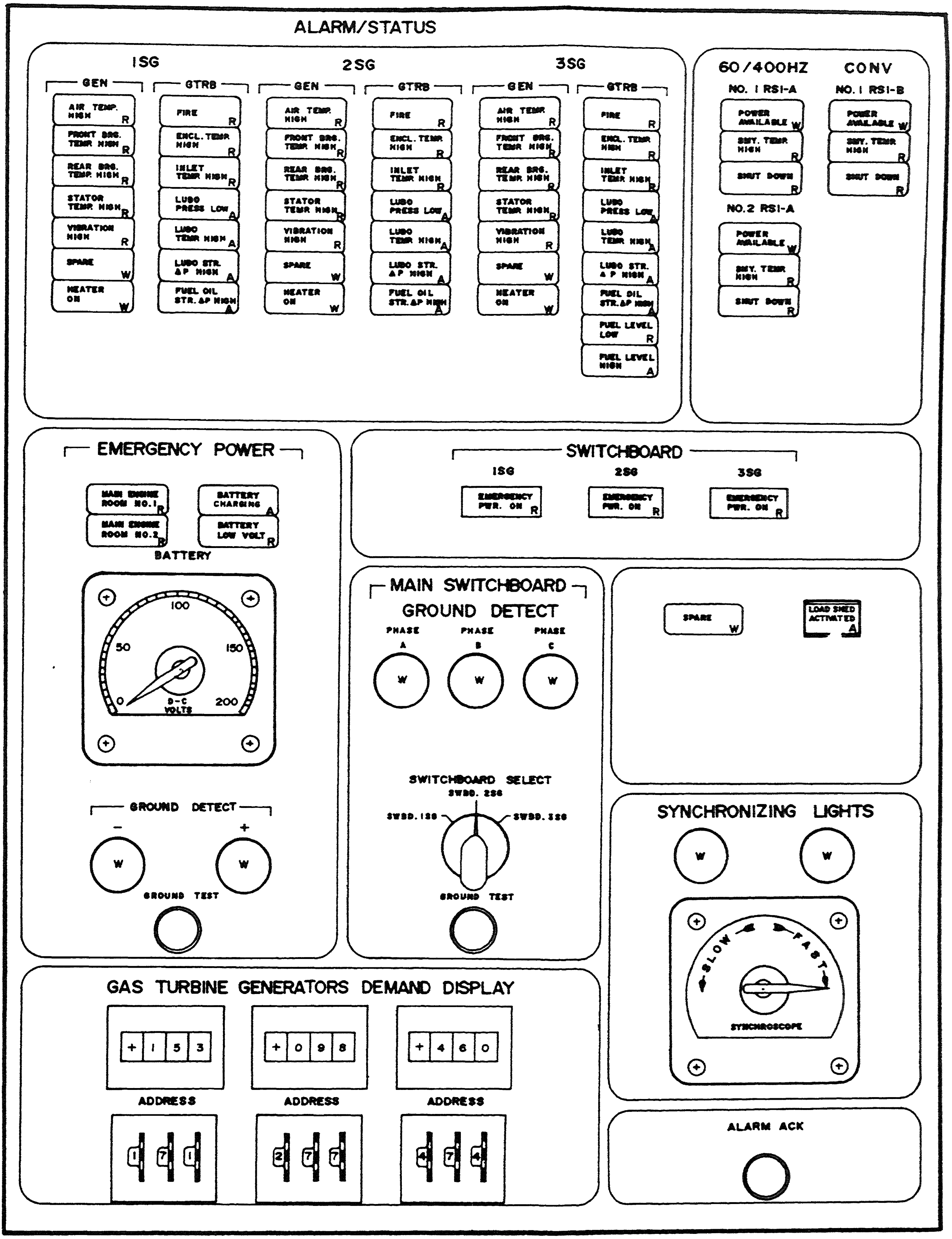

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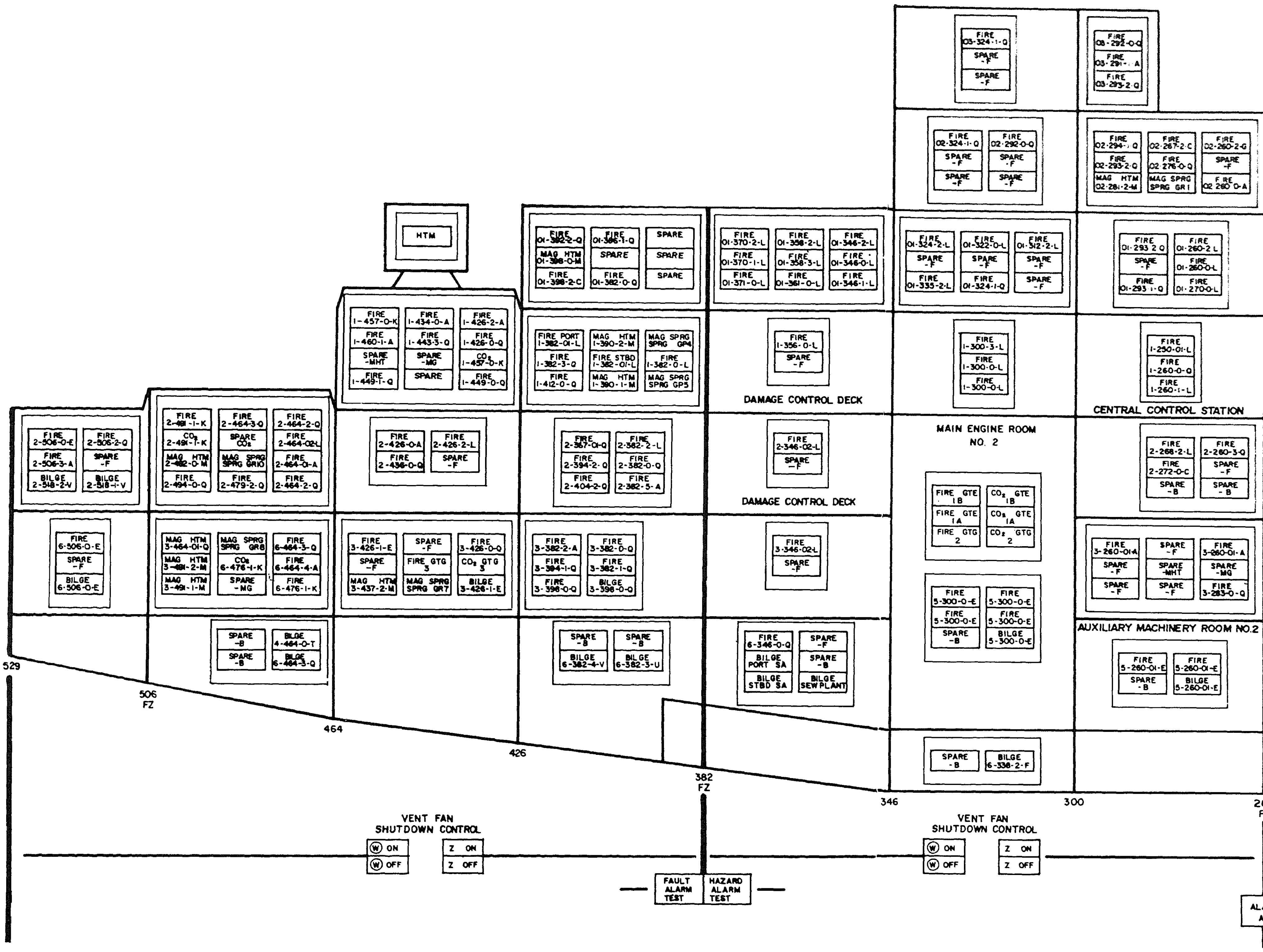
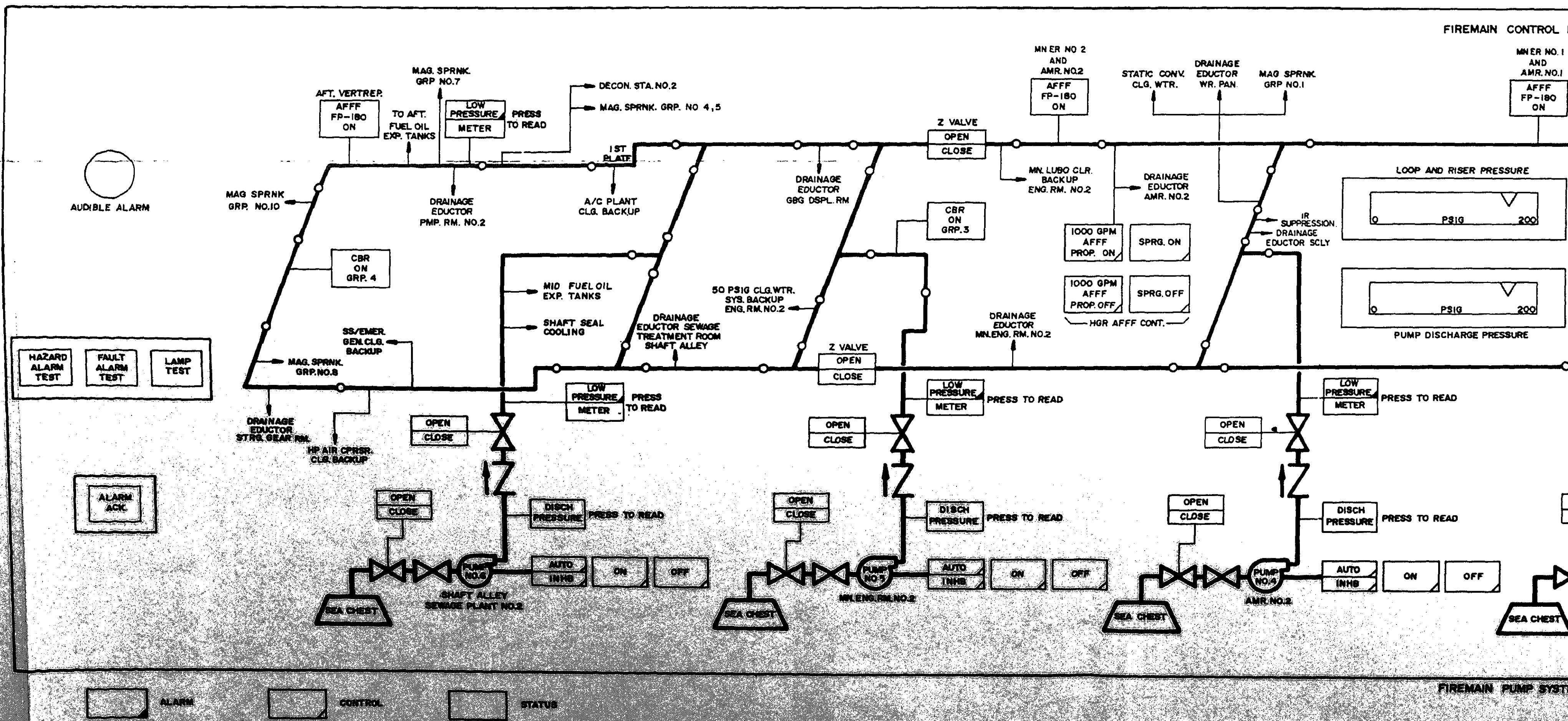
Figure 9-26.—EPCC—alarm/status panel.



HTM
DAMAGE CONTROL DECK
DAMAGE CONTROL DECK
MAIN ENGINE ROOM NO. 2
CENTRAL CONTROL STATION
AUXILIARY MACHINERY ROOM NO.2
529
506 FZ
464
426
382 FZ
346
300
VENT FAN SHUTDOWN CONTROL
W ON
W OFF
Z ON
Z OFF
FAULT ALARM TEST
HAZARD ALARM TEST



FIREMAIN CONTROL
AUDIBLE ALARM
HAZARD ALARM TEST
FAULT ALARM TEST
LAMP TEST
ALARM ACK.
AFT. VERTREP. AFFF FP-180 ON
TO AFT. FUEL OIL EXP. TANKS
MAG. SPRNK. GRP NO.7
LOW PRESSURE METER
PRESS TO READ
DECON. STA. NO.2
MAG. SPRNK. GRP. NO 4,5
MAG SPRNK GRP. NO.10
CBR ON GRP. 4
DRAINAGE EDUCTOR PMP. RM. NO.2
A/C PLANT CLG. BACKUP
1ST PLATF
DRAINAGE EDUCTOR GBG DSPL. RM
Z VALVE
OPEN
CLOSE
MN ER NO 2 AND AMR NO.2
AFFF FP-180 ON
STATIC CONV. CLG. WTR.
DRAINAGE EDUCTOR WR. PAN
MAG SPRNK GRP NO.1
MN. LUBO CLR. BACKUP ENG. RM. NO.2
DRAINAGE EDUCTOR AMR. NO.2
CBR ON GRP. 3
1000 GPM AFFF PROP. ON
SPRG. ON
1000 GPM AFFF PROP. OFF
SPRG. OFF
HGR AFFF CONT.
IR SUPPRESSION
DRAINAGE EDUCTOR SCLY
MID FUEL OIL EXP. TANKS
SHAFT SEAL COOLING
DRAINAGE EDUCTOR SEWAGE TREATMENT ROOM SHAFT ALLEY
50 PSIG CLG. WTR. SYS. BACKUP ENG. RM. NO.2
DRAINAGE EDUCTOR MN.ENG. RM. NO.2
SS/EMER. GEN. CLG. BACKUP
MAG. SPRNK. GRP. NO.8
DRAINAGE EDUCTOR STRG. GEAR RM.
HP AIR CPRSR. CLG. BACKUP
MN ER NO.1 AND AMR. NO.1
AFFF FP-180 ON
LOOP AND RISER PRESSURE
PSIG
200
PUMP DISCHARGE PRESSURE
DISCH PRESSURE
PRESS TO READ
AUTO INHB
ON
OFF
SEA CHEST
SHAFT ALLEY SEWAGE PLANT NO.2
MN. ENG. RM. NO.2
AMR. NO.2
ALARM
CONTROL
STATUS
FIREMAIN PUMP SYST

CHAPTER 10

CENTRAL CONTROL STATION OPERATIONS (OLIVER HAZARD PERRY CLASS)

GSEs on *Oliver Hazard Perry* (FFG-7) class ships, like those on the *Spruance* class, stand a majority of their watches in the central control station (CCS). The watches in the CCS are responsible for operating and monitoring the ship's engineering plant. To stand these watches, you must be familiar with the operation of the equipment in the CCS. This equipment includes the:

- propulsion control console (PCC),
- damage control console (DCC),
- electric plant control console (EPCC),
- auxiliary control console (ACC), and
- bell and data loggers.

This equipment allows the number of watch standers for the entire engineering plant to be kept to a minimum. Alarms and status indicators keep the CCS operators aware of plant conditions; digital displays and meters show them the vital parameters; and switches and pushbuttons allow them control of the equipment.

Just knowing where the lights, pushbuttons, and switches are located is not enough. You must also know the operation of the entire plant. Without operational knowledge of the plant, pushing the wrong pushbutton could endanger equipment, ships' maneuverability, or personnel.

After reading this chapter, you should be familiar with the operation of the equipment in the CCS and how it relates to the engineering plant. We will refer to information covered in chapters 6 and 7 as we discuss the engine-room operation and start sequence of the LM2500.

Like other material in this RTM, this chapter is designed only to familiarize you with the equipment. Use the EOSS and the Personnel Qualification Standard (PQS) to qualify on any watch station.

After reading this chapter and completing the associated NRCC, you should be familiar with the equipment in an FFG-7 CCS. You should have gained enough knowledge to start qualifying on the individual consoles in the CCS. You should also be familiar with the operation of the FFG-7 engineering plant. You may not be assigned to an FFG-7 class ship. However, this chapter should familiarize you enough with the equipment to help you advance in rate. As you become more senior in the GS rating, you may be assigned to an FFG-7 class ship. Then, this indoctrination could be helpful in beginning your qualifications.

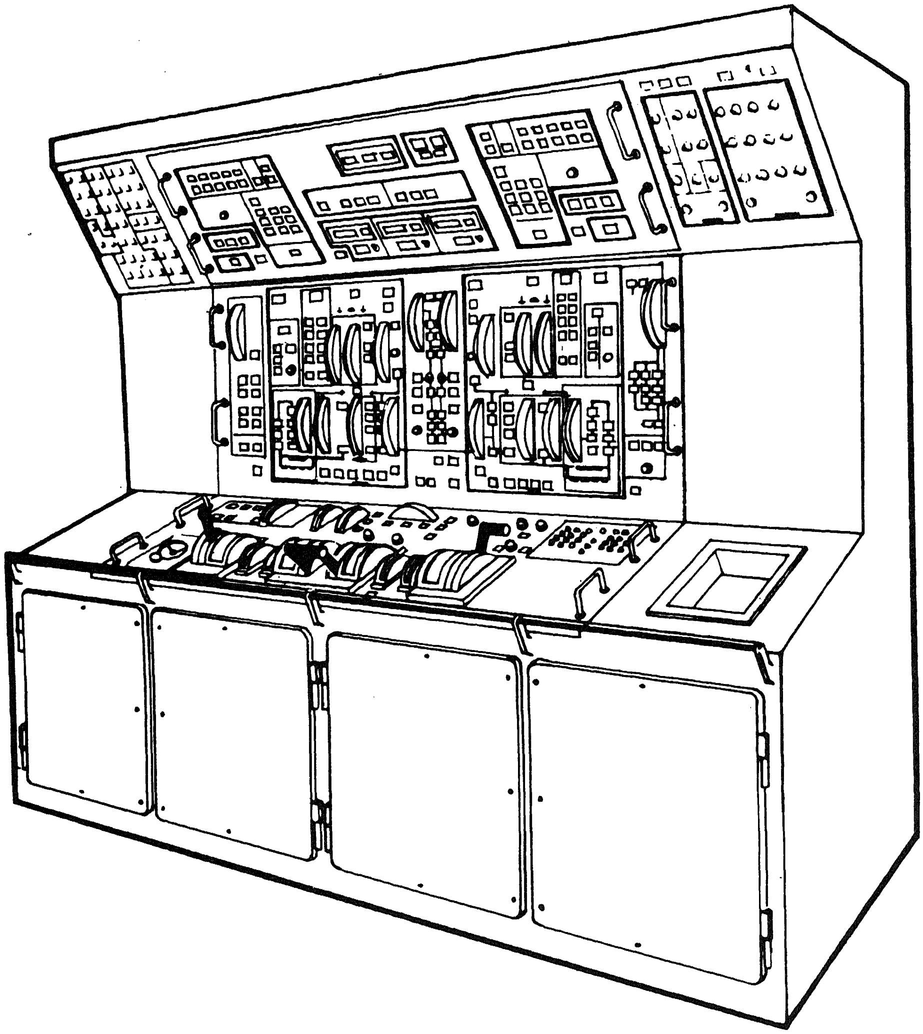
PROPULSION CONTROL CONSOLE

The PCC (figure 10-1) is the console normally used to operate the ship's main engines and propulsion equipment. It is the largest component of the propulsion control system (PCS). The PCC provides all the controls and indicators necessary to start and shut down the ship's propulsion system and its related auxiliaries.

PCC CONTROL MODES

The PCC is used to control the operation of the propulsion system in the programmed control mode or the remote manual control mode.

The programmed control mode is the primary mode for controlling the propulsion system. In this mode the operator controls a single lever. This lever provides an input to a processor. The



227.34.1

Figure 10-1.—Propulsion control console.

processor, in turn, sets the pitch of the propeller blades and the speed of the gas turbine(s).

Two modes of operation are used in the programmed mode, power control or speed control. In the power control mode, the pitch of the propeller is set to maximum. The engines are operated at their lowest possible speeds. The power mode is an open loop, temperature compensated mode using the torque computer in the FSEE to maintain constant engine loading. Power control is also used for low-noise operations. When better maneuvering response is needed, the throttle is operated in the speed control mode. In this mode the ship's speed is changed by changing the propeller pitch up to maximum with shaft rpm remaining constant. In the speed mode, shaft rpm remains constant while built-in power schedules of the program vary engine speed. The speed mode is also called closed loop, constant shaft speed mode.

Do not use the programmed control mode when the pitch of the propeller is being set from the oil injection box or when pitch is locked at full ahead. The reason for this is that the processor does not know when the pitch is operated manually or is locked. Because of this, the

processor would continue computing and transmitting propeller pitch commands, resulting in damage to the equipment.

The remote manual mode at the PCC is used when a gas turbine is started from the PCC. It is also an alternate method of operating the propulsion equipment. This method requires the operation of three levers, for propeller pitch and the speed of each gas turbine. Normally, a combination of programmed control and remote manual control is used only when engines are started or stopped, when maintenance is performed, or when damage has occurred. When one engine is in programmed control and the other is in remote manual, the pitch is controlled by the programmed control lever. The remote manual pitch lever is inoperative.

GAS TURBINE STARTING AND STOPPING

You can start a gas turbine from the PCC in the automatic or manual mode. In the automatic mode, the operator initiates the start at the PCC. The start/stop sequencer (chapter 7) in the FSEE will start the engine. The sequencer also provides the status indications for the operator to follow the start sequence. Automatic starting is inhibited if the prestart permissives have not been met and the READY TO START indicator at the PCC is extinguished.

Manual starts from the PCC require the operator to activate circuits and sequence the start manually. The start/stop sequencer provides status indications of the start sequence to the operator. Again, the start/stop sequencer prohibits start until the prestart permissives have been met and the READY TO START indicator on the PCC start panel is illuminated.

You can shut down the gas turbine by four modes. Three are operator selectable from the PCC. The modes of stopping are as follows.

- Normal stop—operator initiated
- Manual stop—operator performed
- Emergency stop—operator performed
- Automatic shutdown—logic initiated

Normal stops are performed in the remote manual mode. The operator, following the EOSS, must bring the engine to idle. Depressing the normal stop pushbutton initiates a normal stop sequence, performed by the start/stop sequencer. This causes the engine to run for 5 minutes at idle before fuel valve closure which allows the engine to cool. This cooldown period lengthens engine life.

The operator may perform manual stops from the PCC in the remote manual mode. The operator is required to sequence this stop. The engine should be allowed to run at idle for 5 minutes before the closure of the fuel-shutdown valves.

The PCC operator may activate the emergency stop at any time and in any operating mode, regardless of the console in control. The emergency stop is initiated by depressing the emergency stop pushbutton. This causes the engine's fuel valves to immediately close.

Automatic shutdowns may occur when the engine is started or running. The automatic shutdowns de-energize the fuel valves. This causes the engine to shut down. The conditions during start that cause an automatic shutdown are as follows.

- N_{GG} fails to reach 1200 rpm within 20 seconds after start is initiated.
- Failure to reach 400 °F $T_{5.4}$ within 40 seconds after the fuel valves are energized.
- N_{GG} fails to reach 4500 rpm within 90 seconds after start is initiated.
- Engine lube oil pressure is below 6 psig 45 seconds after start is initiated or engine speed is above 4500 ± 200 rpm.

During engine operation, the following conditions cause an automatic shutdown.

- GG flameout—$T_{5.4}$ below 400 °F with fuel manifold pressure above 50 psig
- $T_{5.4}$ above 1530 °F
- N_{pt} above 3960 ± 40
- Engine lube oil pressure less than 6 psig

- GG vibration above 7 mils
- PT vibration above 10 mils

NOTE: Battle override inhibits all automatic shutdowns except flameout and PT overspeed.

PCC CONTROLS AND INDICATORS

The PCC is subdivided into panels (figure 10-2). In the center of the top section of the PCC is the demands panel. On either side of the demands panel are the engine start panels (1A on the right side, 1B on the left side). On the middle section of the PCC from left to right are the (1) seawater cooling panel, (2) engine 1B panel, (3) fuel oil service panel, (4) engine 1A panel, and (5) reduction gear lube oil panel. The lower section of the PCC is the propulsion panel. This panel has the throttle controls and the propeller pitch hydraulic oil panel. On the top outboard sections of the console are a fuse panel and a fuse and status panel.

Follow the related figures as we discuss the various PCC control and indicating panels. The parenthetical letters are shown on the figures.

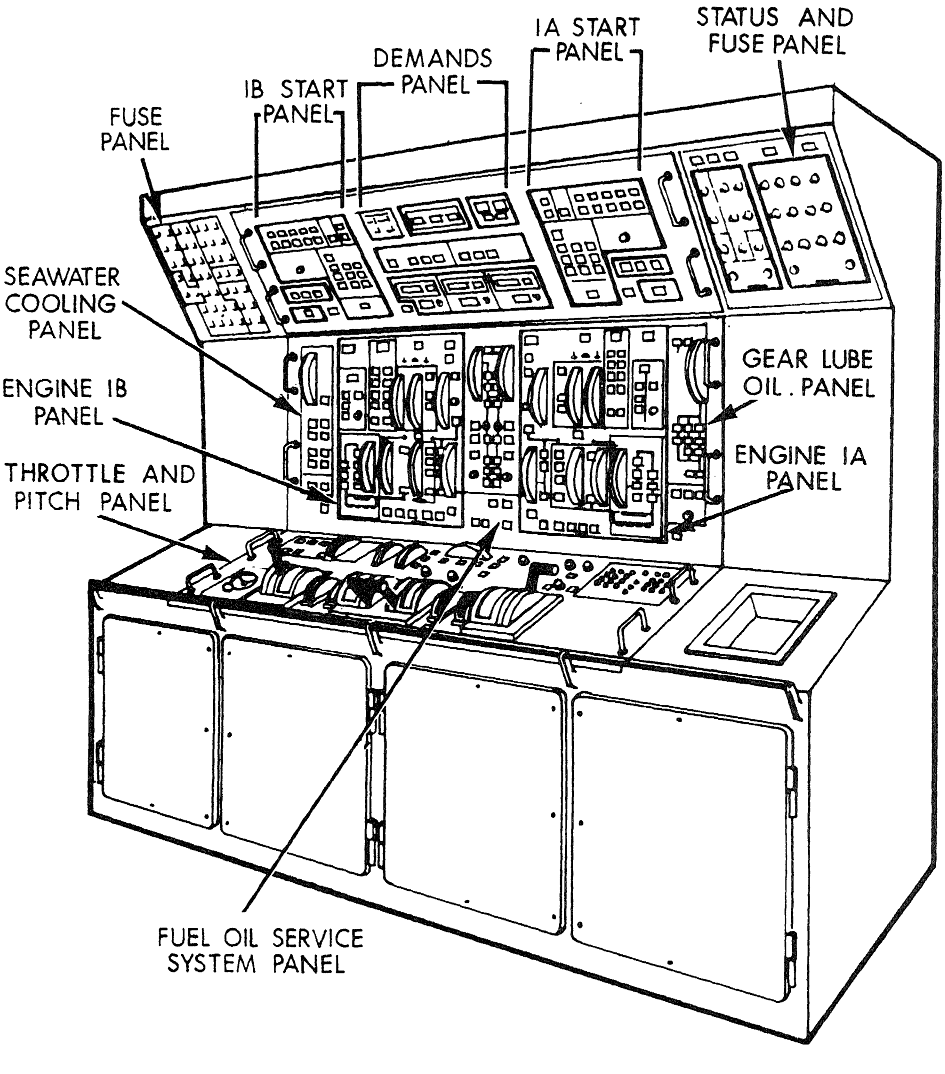


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Figure 10-2.—PCC panel breakdown.

Refer to these letters to find the section of a panel when it is discussed.

Demands Panel

The demands panel (figure 10-3) has information and controls such as status, time, logger commands, power supply status, and selected parameter values.

AUTO SHUTDOWN STATUS.—The auto shutdown status indicators (A) illuminate red when an auto shutdown occurs, either on engine 1A or 1B. An auto shutdown may occur because of vibration, low lube oil pressure, or high $T_{5.4}$. These are reset when the automatic shutdown is reset.

TIME.—The time section (B) has a digital display using LEDs of the time generated by the PCC real-time clock.

LOGGER COMMANDS.—The logger section (C) has two sets of thumbwheels and two pushbutton switches. The thumbwheels are used to set the month and day into the processor for use on the automatic logger. These must be updated daily. The pushbuttons cause the data or bell logger to print, depending on which is selected.

POWER.—The power section (D and E) of the demands panel is divided into two sections, the propulsion control console (D) and the local operating panel (E). These two sections provide power supply status for the logic power supplies

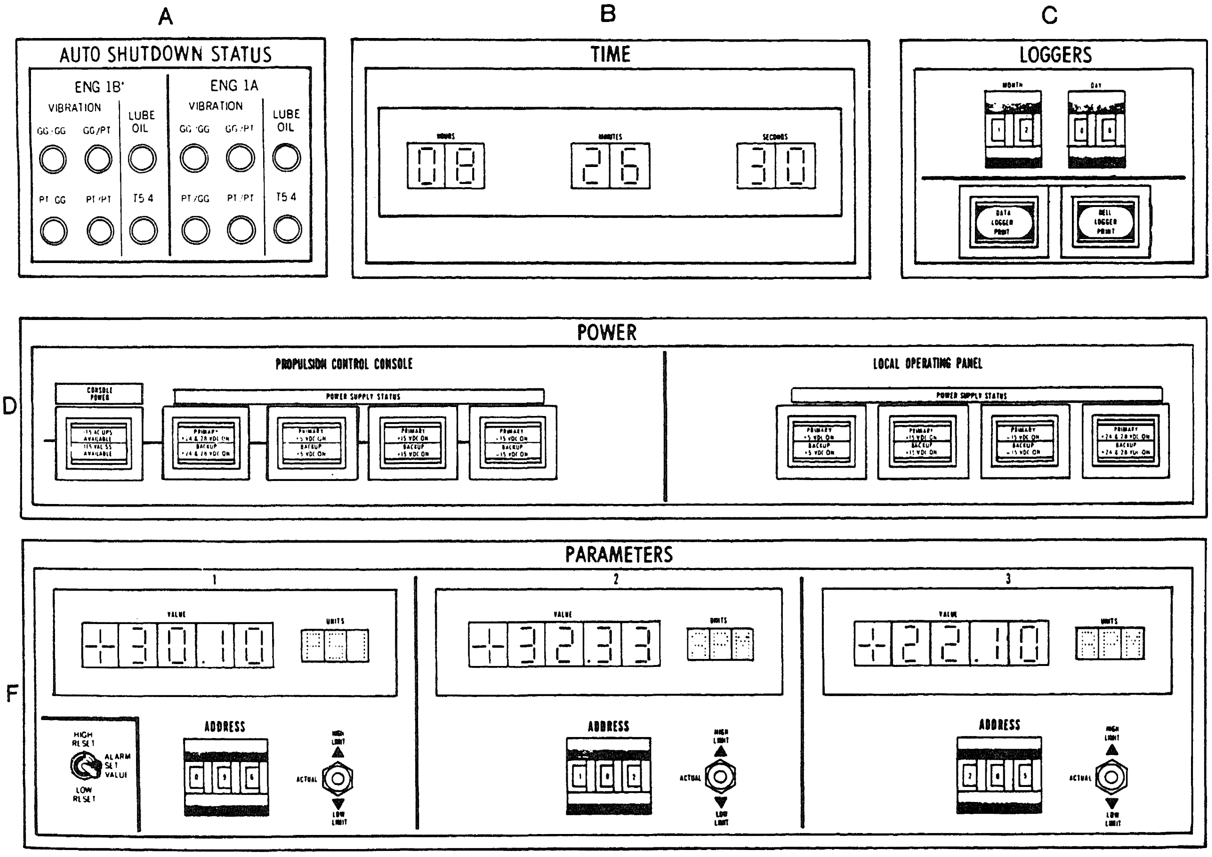

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Figure 10-3.—Demands panel,

in the PCC and LOP. They also provide console status for the PCC. These indicators are split-type and both halves are normally illuminated. If either half of an indicator is dark, check the power supplies for malfunctions.

PARAMETERS.—The parameters section (F) has three digital display sections. Each contains a display, a thumbwheel, and a toggle switch. The digital displays are also found on the EPCC and the auxiliary control console (ACC). The thumbwheel is used to select an address, found on a DDI listing, that calls up the selected parameter. The parameter is displayed with the decimal in the proper position and with the units used to measure the parameter (psi, rpm, and so forth). A toggle switch is also used to display either the high-alarm limit, the actual value, or the low-alarm limit. A second toggle switch, used in conjunction with this first toggle switch, allows the operator to verify the high/low reset value of the alarm.

Engine Start Panels

The two engine start panels (figure 10-4) are mirror images of each other. They have identical pushbuttons and indicators. These indicators and controls are used to monitor or control the start of one of the gas turbines.

PRESTART STATUS.—The prestart status section (A) has ten split indicators used to display the status of components in the plant before start. There are a total of 18 indicators on this section. Starting on the top outside indicator and going across the top row, the indicators are as follows.

1. PROP PITCH ZERO	Propeller pitch is at zero (bypassed for second engine).
2. SHAFT BRAKE DISENGAGED	Shaft brake is disengaged (bypassed for second engine).
3. TURN GEAR NOT ENGAGED	The turning gear motor is not engaged to the gearbox and is not locked.
4. ACC COVER CLOSED	Clutch access doors for both engines are closed.
5. STARTER NOT MOTORING	Engine starter is not motoring (turning).
6. ENGINE WASH OFF	Engine is not being water washed.
7. SEAWATER COOLING ON	Seawater cooling pressure is greater than 7 psi, and the discharge valve is open.
8. GEAR LUBE OIL ON	MRG lube oil supply pressure is greater than 9 psi.
9. BLEED AIR VALVE CLOSED	Bleed air valve on that engine is closed.
10. LOP NOT IN CONTROL	Control of the engine is not at the LOP.
11. ENGINE NOT RUNNING	N_{GG} is less than 1200 rpm, $T_{5.4}$ is less than 400°F, and fuel manifold pressure is less than 50 psi.
12. ENCL FANS READY	Enclosure fan is ready to run depending upon automatic fan circuitry.
13. PT BRAKE NOT ENGAGED	The PT brake for that engine is not engaged.
14. FUEL SUPPLY ON	One of the two fuel tanks has more than 20%, the fuel supply cutoff valve is open, and the fuel supply pressure is greater than 8 psi.

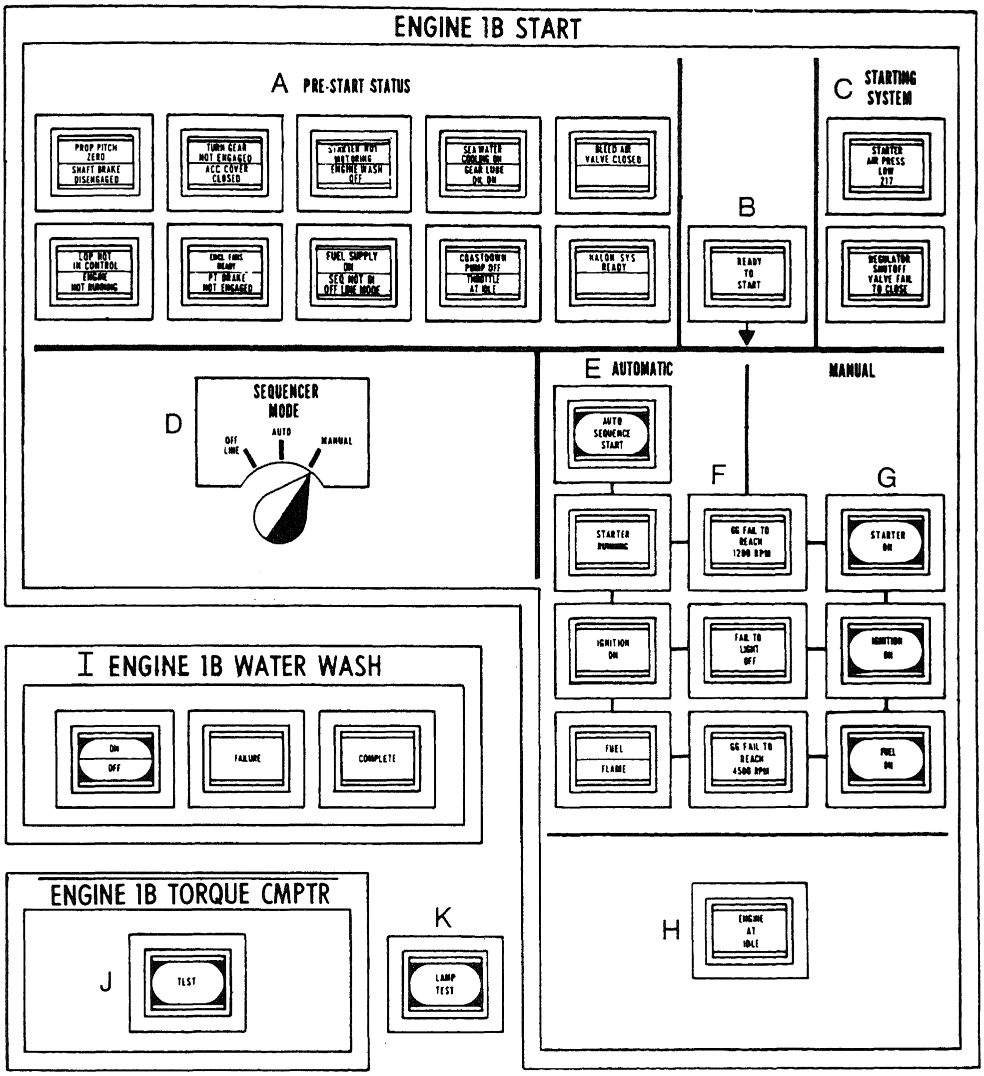

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Figure 10-4.—Engine start panel (1B shown, 1A is mirror image).

15. SEQ NOT IN OFF-LINE MODE	The sequencer mode switch is not in the off-line position.
16. COASTDOWN PUMP OFF	The coastdown pump is not running.
17. THROTTLE AT IDLE	The engine PLA is setting at the idle position.
18. HALON SYS READY	The Halon inhibit switch is not on and the Halon system is ready.

READY TO START.—The READY TO START indicator (B) only illuminates when the 18 prestart permissives have been met. The engine cannot be started in either the automatic or manual mode until this indicator is illuminated.

STARTING SYSTEM.—The starting system section (C) has two indicators used to display

abnormal conditions in the starting air system. The STARTER AIR PRESS LOW indicator illuminates when the starting air pressure drops below 35 psi as sensed by one of two pressure transducers. The REGULATOR SHUTOFF VALVE FAIL TO CLOSE indicator illuminates when the start air valve on the GT has not closed and the GG speed has reached 4900 rpm.

SEQUENCER MODE SELECTOR SWITCH.—The sequencer mode selector switch (D) is a three-position rotary switch used to determine the operating mode of the start/stop sequencer. The three modes are off-line, auto, and manual. The off-line position will prevent the engine from being started at the PCC. This mode is normally used only during maintenance, water washing, and motoring. The auto position allows the AUTO SEQUENCER START pushbutton to be used to start the engine using the start/stop sequencer. In the manual position, the operator has to start the engine using the manual pushbuttons and do the sequencing.

START SEQUENCING.—The start sequencing section (E, F, G, and H) has ten pushbuttons and indicators used to control or monitor the engine start. The automatic start section (E) has a pushbutton and three indicators used to start the engine in the automatic mode. The AUTO SEQUENCE START pushbutton is depressed to initiate the auto start sequence in the start/stop sequencer. This action will only start the sequence if the sequencer mode select switch (D) is in AUTO, and the READY TO START indicator (B) is illuminated. The first indicator to illuminate during an auto start sequence is the STARTER RUNNING indicator. This shows the starter regulator/shutoff valve is open. The next indication is for IGNITION ON. This indicator shows that the igniters are energized through the start/stop sequencer. The third indicator is a split-type that reads FUEL/FLAME. The FUEL indicator illuminates when the fuel manifold pressure is greater than 50 psi. The FLAME indicator illuminates when $P_{t5.4}$ is greater than 400 °F.

The three center indicators (F) are used to show out-of-tolerance conditions during an engine start. These three conditions will also cause an automatic shutdown. These indicators illuminate when (1) N_{GG} FAILS TO REACH 1200 RPM, (2) the engine FAILS TO LIGHT OFF, or (3) N_{GG} FAILS TO REACH 4500 RPM. The parameters for these alarms were detailed earlier.

The three manual start pushbuttons (G) are used to manually sequence the start/stop sequencer during a manual start. The pushbuttons are labeled STARTER ON, IGNITION ON, and FUEL ON. These pushbuttons are used when the sequencer mode selector switch (D) is in the MANUAL or OFF-LINE mode. The STARTER ON pushbutton, when depressed, opens the starter shutoff/regulator valve. Depressing it again will close the valve, although it will automatically close at 4500 rpm (N_{GG}). The IGNITION ON pushbutton is a momentary pushbutton switch. When this pushbutton is depressed, it energizes the igniters. It de-energizes them when it is released. The FUEL ON pushbutton is also a momentary-type switch. Depressing it causes the fuel valves to open. During a start, these valves are latched open by the sequencer.

The ENGINE AT IDLE lamp (H) is illuminated when N_{GG} is between 4900 and 5000 rpm.

WATER WASH.—The engine water wash section (I) has one split-legend latching-type pushbutton switch and two indicators. The ON/OFF indicator switch is enabled (1) when the water wash control is in REMOTE at the engine room controller, (2) the sequencer mode switch on the PCC is in the OFF-LINE position, and (3) the engine control mode switch is in the PROGRAMMED position. When these conditions have been met, depressing the ON/OFF switch signals the processor to start the engine wash sequence. FAILURE, an alarm indicator, illuminates if any of the following conditions occur: (1) initially if the wash and the rinse tanks are not full, (2) if once the wash cycle has started and the wash tank is not empty within 4 minutes, and (3) if the rinse tank is not empty within 10 minutes. The COMPLETE indicator illuminates when the automatic engine wash cycle has been completed.

TORQUE COMPUTER.—The torque computer TEST pushbutton/indicator (J) is used to perform a confidence check of the engine torque computer. When this pushbutton is depressed, it

"plugs in" a set of fixed values that replace the normal engine parameters to calculate the engine's torque and horsepower. These calculated values are then compared to fixed reference values in the FSEE. If the result is correct, the TEST pushbutton/indicator illuminates by a "test passed" signal from the FSEE. If it does not illuminate, the torque computer is not working correctly. This test should only be done when the engine is secured or at idle. This is because the normal engine parameters are being replaced with a fixed set of parameters and there is no overtorque protection during this time.

LAMP TEST.—The LAMP TEST (K) pushbutton is used to check the condition of the lamps. When it is depressed, all the indicators and switches on the panel should illuminate, except the heater indicator.

Main Seawater Cooling Panel

The main seawater cooling panel (figure 10-5) is located on the left side of the middle panel of the PCC. It is used to control and monitor the operation of the engine-room main seawater system. This system is used to cool the reduction gear lube oil. The control available from this panel allows opening and closing of three valves and start/stop control of two pumps. The three valves controlled from the PCC are pump 1A suction valve, pump 1B suction valve, and the overboard discharge valve. (NOTE: The panel is labeled for pump and suction valves 1 and 2. Pump 1 controls 1A pump and suction valve 1 controls 1A suction valve. Pump 2 controls 1B pump and suction valve 2 controls 1B suction valve.) Each valve has an OPEN/CLOSE pushbutton to operate the valve and an OPEN/CLOSED indicator to show actual valve status. Also, each pump has an ON/OFF pushbutton to start and stop the pump as well as a RUNNING/OFF indicator to show the status of the pump.

A LOW PRESSURE alarm and a supply pressure meter are used to monitor main seawater cooling pressure. Normal pressure is 30 to 35 psig. The low seawater alarm will sound at 7 psig with a 10-second delay.

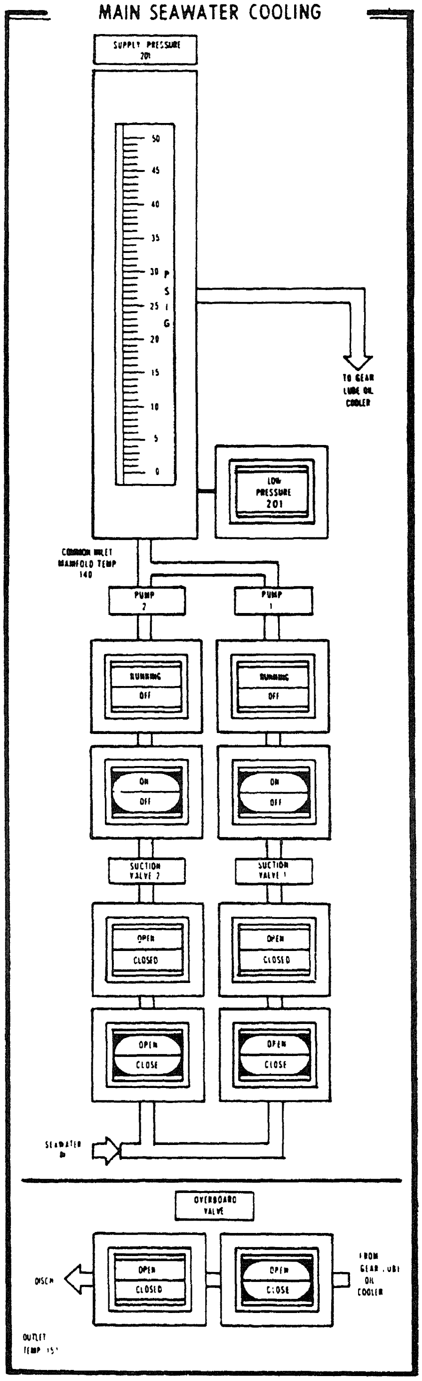

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Figure 10-5.—Main seawater cooling panel.

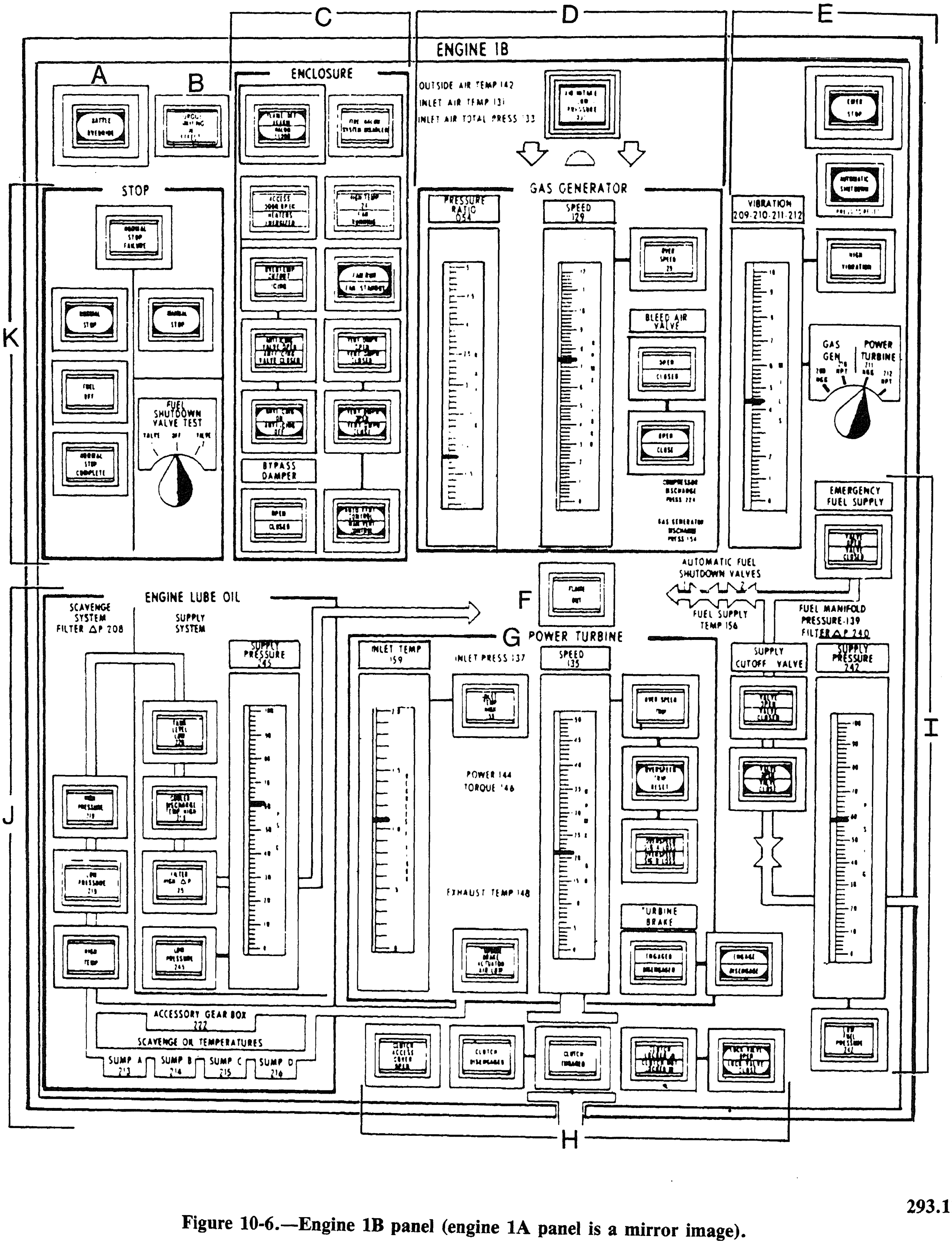

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Figure 10-6.—Engine 1B panel (engine 1A panel is a mirror image).

Engine Panel

The PCC engine panel (figure 10-6) has many of the same controls and indicators found on the LOP. It contains the controls, indicators, and meters needed to remotely operate the GTs. The engine 1A and 1B panels are mirror images of each other. We will cover the engine 1B panel in our discussion; keep in mind that the 1A panel has identical features.

BATTLE OVERRIDE.—BATTLE OVERRIDE (A) is a guarded, illuminated pushbutton. You can use it only if the PCC is the station in control. It is illuminated when on. This switch overrides the following shutdowns.

1. GTM low lube oil pressure
2. High engine vibration
3. High $T_{5.4}$
4. Power lever angle failure for:
   a. PCS command signal out of limits
   b. PT shaft torque out of limits
   c. PT speed out of limits

It does not override a flameout or a PT overspeed trip.

TORQUE LIMITING IN EFFECT.—The TORQUE LIMITING IN EFFECT indicator (B) illuminates any time the torque limiting circuit is restricting the advancing of the PLA. This is done until the torque on the engine is within safe limits. Then the torque limiting circuit will allow the PLA to advance to the command position, provided the PLA doesn't send the engine into an over-torque condition. If it does, then the torque limiting circuit will take over again as before. This will continue until the command is obtained, or the command is reduced to a lower setting.

ENCLOSURE.—The location of the enclosure section (C) on the engine 1B panel is shown in figure 10-6. Figure 10-7 is an enlarged view of this section. The following paragraphs describe the switch/indicators of the enclosure section. The first switch/indicator (A) is located on the top left-hand side of the enclosure section. It is a split indicator. The upper half is FLAME DET ALARM. When it is illuminated, the UV sensor has sensed a flame in the enclosure. The

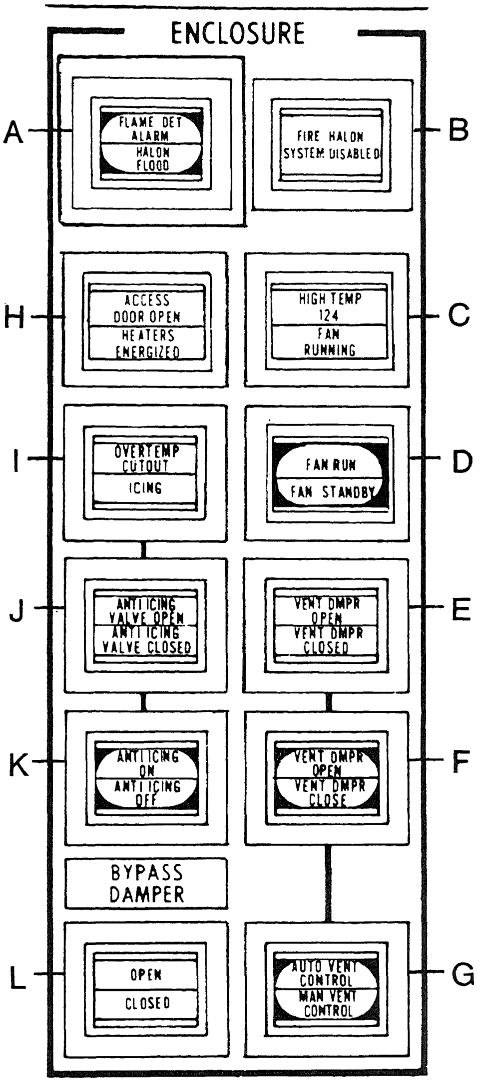

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Figure 10-7.—Enclosure section of an engine panel.

lower half, HALON FLOOD, is the switch. Depressing this switch releases the primary bank of Halon. This occurs if the manual inhibit switch is in the active position at the enclosure. NOTE: There is no automatic release of Halon into the enclosure.

The FIRE/HALON SYSTEM DISABLED indicator (B) is next to the FLAME DET ALARM indicator. It is illuminated when a loss of continuity in the fire or the Halon system occurs. This is caused by loss of continuity between the flame

detector and signal conditioner or loss of 115-volt a.c. power to the detection system. Power is supplied by the 115-volt a.c. CB in the FSEE.

The next indicator down is a split-legend indicator (C). The upper half, HIGH TEMP, is the indicator being fed from the two temperature switches (set at 400 °F) in the enclosure. The lower half, FAN RUNNING, is illuminated when the enclosure fan is running.

The next indicator down (D) is a switch/indicator, FAN RUN/FAN STANDBY. It selects the mode of operation for the ventilation fan. In the FAN RUN position, the fan will be running. In the FAN STANDBY position, the fan automatically starts when:

- the engine is running below 3000 hp; or
- the engine is not running and the enclosure temperature is above 125 °F.

The fan automatically shuts down when:

- Halon is discharged into the enclosure;
- the engine is running above 3000 hp;
- the engine is not running and the enclosure temperature is below 125 °F; or
- the vent damper closes.

To start a gas turbine engine, the fan controller must be in the remote position and the control on the PCC should be in the standby position.

The last three indicators down (E, F, and G) are for the vent damper. The VENT DMPR OPEN/VENT DMPR CLOSED indicator (E) shows the position of the vent damper. The VENT DMPR OPEN/VENT DMPR CLOSE switch/indicator (F) is for manual control. It is only functional when the AUTO VENT CONTROL/MAN VENT CONTROL switch/indicator (G) is in the MAN VENT CONTROL position.

The AUTO VENT CONTROL/MAN VENT CONTROL switch/indicator is used to select the mode of operation for the ventilation damper, either automatic or manual. In automatic mode, the ventilation damper will open when:

- the ventilation fan is running;
- the engine is running; or
- the engine is not running and the outside air temperature is above 70 °F.

The damper will close automatically when:

- Halon is discharged into the enclosure; or
- the engine is not running and the outside air temperature is below 70 °F.

In the manual mode, damper control circuits automatically close the damper if Halon is discharged into the enclosure.

At the top of the next column is the ACCESS DOOR OPEN/HEATERS ENERGIZED indicator (H). The upper half is fed from switches at the two doors. The fuel/enclosure heater keeps the enclosure air temperature above 60 °F. This temperature is required to prevent fuel waxing (fuel hardening) in the engine fuel system. The ceiling-mounted heater is a forced air space heater rated at 8 kW. The heater is electrically powered and thermostatically controlled. It is energized when the inlet air temperature is 60 ° to 70 °F. It is de-energized when the temperature reaches 85 ° to 90 °F. Overtemperature protection and a manual reset are provided. Air circulation is provided by a blower when temperatures are below 125 °F. Blower operation stops when the temperature reaches 145 °F. Control of the heater is provided on the LOP. Indication of the heater status is provided on both the PCC and the LOP.

The OVERTEMP CUTOUT indicator (I) will illuminate when the heater is de-energized because the enclosure temperature was 145 °F and the heater was on.

The ICING detector indicator (I) measures the temperature and humidity of the incoming combustion air. When icing conditions occur, temperature below 41 °F and humidity above 70 percent, an alarm is provided at the PCC.

The ANTI-ICING VALVE OPEN/ANTI-ICING VALVE CLOSED indicator (J) shows the actual position of the anti-icing valve. Below this indicator is the ANTI-ICING ON/ANTI-ICING OFF control switch/indicator (K). It is used to control the anti-icing valve.

The last indicator in this section is the BYPASS DAMPER. The bypass damper, mounted in the cooling air bypass intake trunk, opens to provide an air path from the atmosphere to the GT enclosure; it closes to prevent the reverse flow of air through the bypass intake trunk when the cooling fan is running. Switches at the bypass damper provide signals to the PCS to show the

OPEN/CLOSED status (L) of the bypass damper at the PCC.

GAS GENERATOR.—The location of the GG section (D) on the engine 1B panel is shown in figure 10-6. It has meters and indicators for the GG section of the engine. Figure 10-8 is an enlarged view of this section. The AIR INTAKE LOW PRESSURE alarm (A) is used to indicate when the differential pressure exceeds 7.5 in. H_2O. This is measured between the ambient air and the combustion air intake, downstream from the moisture separator. The PRESSURE RATIO meter (B) monitors, over a long period of time, the condition of the GG. The input of this meter comes from computations between the P_{t2} and $P_{t5.4}$.

The GG SPEED meter (C) displays the speed of the GG. Associated with this meter is the OVERSPEED alarm (D) which has a set point of 9700 ± 100 rpm. Below the OVERSPEED indicator are the controls and indicators for the bleed air valve. The OPEN/CLOSED indicator (E) displays the actual position of the valve. The OPEN/CLOSE pushbutton control (F) is used to open and close the valve.

EMERGENCY STOP AND VIBRATION.—The locating of the EMERGENCY STOP and VIBRATION section (E) on the engine 1B panel is shown in figure 10-6. Figure 10-9 is an enlarged view of this section.

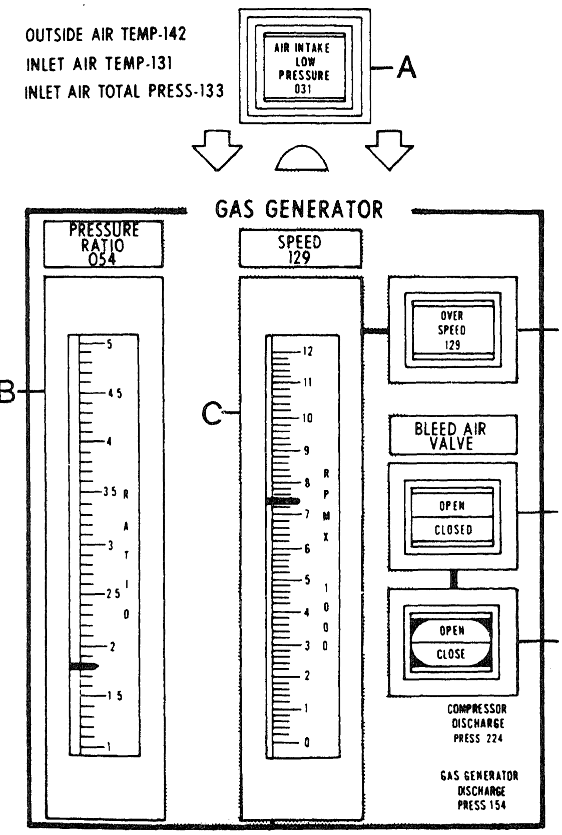

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Figure 10-8.—Gas generator section of the engine panel.

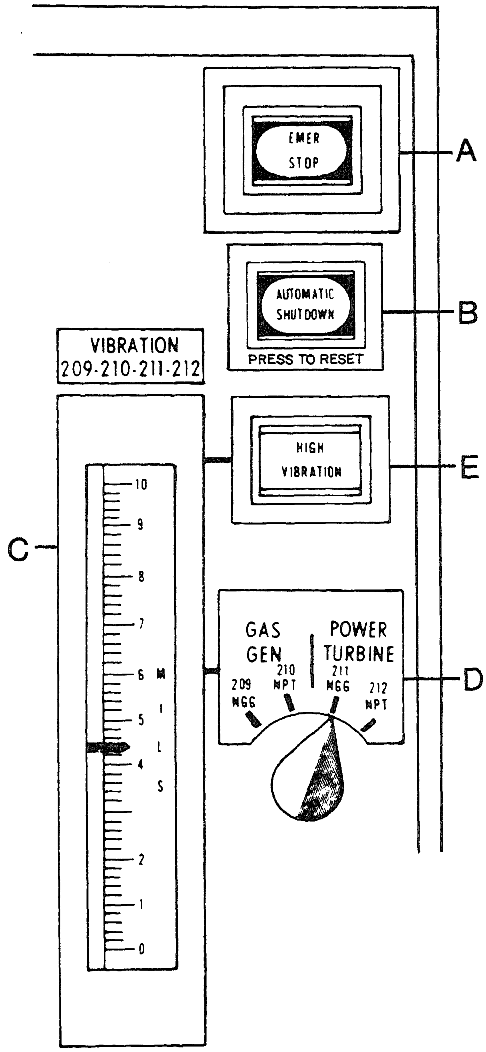

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Figure 10-9.—Emergency stop and vibration section.

Emergency Stop Switch/Indicator.—The EMER STOP switch/indicator (A) can be initiated by the operator at any time and in any control mode. Depressing the EMER STOP indicator switch on the PCC causes the circuitry in the LOP and the FSEE to immediately de-energize the PT overspeed trip switch. This causes both automatic fuel shutdown valves to close which causes the engine to shut down.

Automatic Shutdown Switch/Indicator.—The AUTOMATIC SHUTDOWN switch/indicator (B) indicates that an automatic shutdown has occurred. This switch resets the automatic shutdown electronics. The PCS initiates automatic shutdown for the following parameters after a GTE is running and provides indication of each shutdown on the PCC.

1. $T_{5.4}$ above 1530°F
2. GT engine oil pressure below 6 psig
3. GT high vibration (GG above 7 mils or PT above 10 mils)
4. Flameout ($T_{5.4}$ less than 400°F after PT fuel manifold pressure becomes greater than 50 psi and after an engine run signal is obtained)

Vibration.—This section has a meter, switch, and an indicator. The meter (C) is always reading the vibration on the engine at the position selected by the switch. The switch (D) is a four-position switch. It allows you to look at the two different vibration pickups. One is located on the GG and the other is on the PT. Each pickup senses both GG and PT vibration. A tracking filter for each pickup separates GG vibration from PT vibration depending on vibration frequency. Limits apply to frequency and not pickup location. The HIGH VIBRATION indicator (E) will illuminate when the vibration on the GG reaches 4 mils and the PT reaches 7 mils. An automatic shutdown occurs when GG vibration reaches 7 mils and PT vibration reaches 10 mils.

FLAMEOUT.—The FLAMEOUT indicator (figure 10-6, item F) will illuminate when $T_{5.4}$

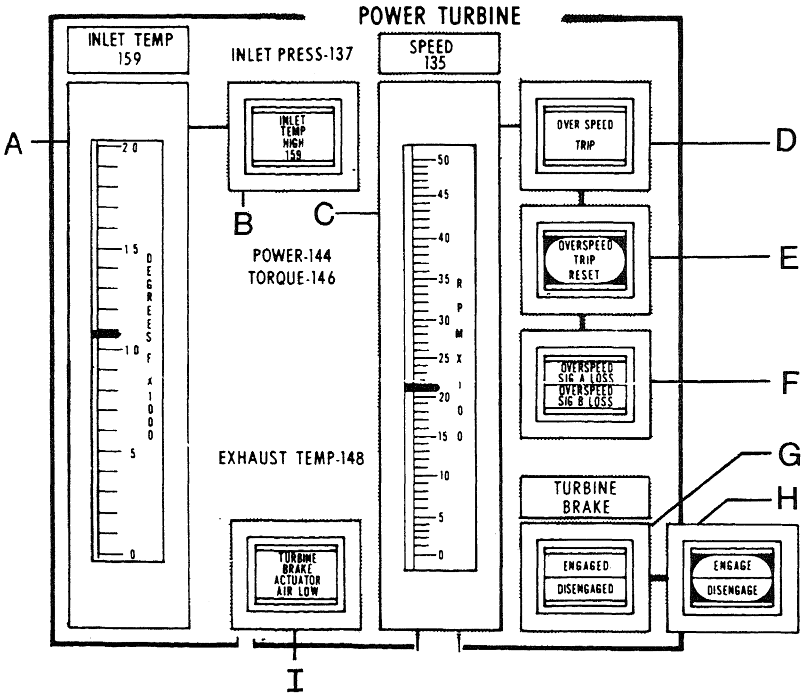

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Figure 10-10.—Power turbine section of the engine.

ops below 400°F after the fuel manifold essure becomes greater than 50 psi and after an gine run signal is obtained. When this happens, automatic shutdown will ensue.

POWER TURBINE.—The location of the PT ction (G) on the engine 1B panel is shown in gure 10-6. Figure 10-10 is an enlarged view of is section. The PT section monitors the opera- on of the PT. It has two meters, two push- ıttons, and five indicators.

The first meter is the INLET TEMP ($T_{5.4}$) eter (A). It displays the temperature of the gas tering the PT. Associated with this meter is the ILET TEMP HIGH alarm indicator (B) for high $_{5.4}$. It has an alarm set point of 1500°F. An tomatic shutdown will occur if $T_{5.4}$ reaches 30°F and battle override is not on.

The second meter, the PT SPEED meter (C), ows the speed of the PT. The meter is fed from o sensors mounted on the rear frame of the rbines that sense PT speed.

To the right of this meter is an OVERSPEED RIP indicator (D). It illuminates if either the sensors senses a PT speed greater than 60 ± 40 rpms. This condition causes the engine shut down because the fuel shutdown valves e de-energized.

Directly below this indicator is the OVER- PEED TRIP RESET pushbutton (E). It is used reset the overspeed trip and to latch the fuel lves during starting. Next is a split-legend dicator (F) which is labeled OVERSPEED GNAL A LOSS/OVERSPEED SIGNAL B OSS. These indicators will illuminate when the T speed drops below 100 rpms or a malfunction in the circuit occurs. When the PT speed becomes less than the loss of signal setting on both speed signal input channels or greater than the overspeed setting on either speed signal input channel, the fuel shutdown valves de-energize (the engine will shut down). If the PT speed loss signal occurs on only one channel, the engine will continue to run.

The bottom part of this section is used to control and monitor the operation of the turbine brake. The turbine brake indicator (G) displays the actual status of the brake, either ENGAGED or DISENGAGED. The split indicator next to it is used to control the brake. Depressing it will either ENGAGE or DISENGAGE the brake assembly. The TURBINE BRAKE ACTUATOR AIR LOW indicator (I) will display when the air pressure to the brake actuator is too low. It illuminates when brake air pressure is less than 70 psi. The turbine brake may not be engaged unless the PT speed is below 250 rpm and the engine fuel manifold pressure is below 50 psig.

CLUTCH.—The location of the clutch section (H) on the engine 1B panel is shown on figure 10-6. Figure 10-11 is an enlarged view of this section. The clutches on this class ship are synchronized self-shifting. The only operation action required to engage and disengage them is the removal of the brake and operation of the throttle.

This section of the panel has four indicators and one pushbutton. The first indicator (A) in the section is CLUTCH ACCESS COVER OPEN. This indicates that the access door to the clutch is open. The next two indicators (B and C) display the clutch status, either CLUTCH

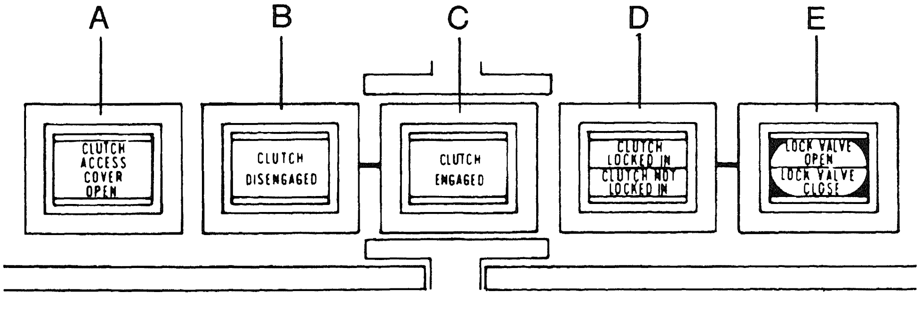

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Figure 10-11.—Clutch section of the engine panel.

DISENGAGED or CLUTCH ENGAGED. The CLUTCH LOCKED IN/CLUTCH NOT LOCKED IN indicator (D) displays the status of the lock-in/lock-out mechanism of the clutch. Locking out the clutch provides for operation of the GT without turning the MRG. For normal operation the clutch must be locked in. The last control (E) is a pushbutton no longer in use. Previously, it was used to operate the lock valve.

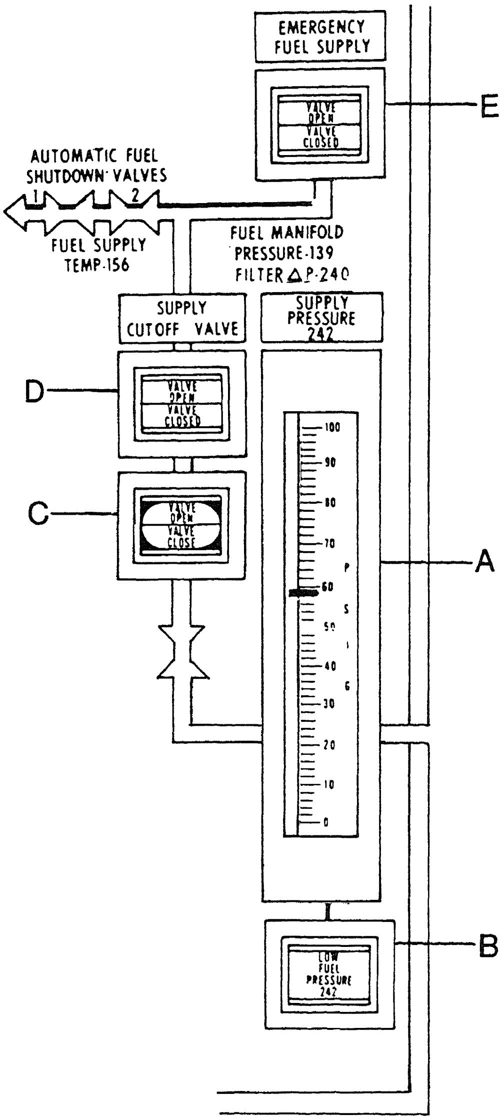

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Figure 10-12.—Engine fuel supply section of the engine panel.

ENGINE FUEL SUPPLY.—The location of the engine fuel supply section (I) on the engine 1B panel is shown on figure 10-6. Figure 10-12 is an enlarged view of this section. It has the control and monitor components used to operate the fuel supply to the engine.

The SUPPLY PRESSURE meter (A) displays the pressure of the fuel from the fuel service system to the engine. Associated with this meter is the LOW FUEL PRESSURE alarm (B) which sounds at 8 psi. Fuel supply pressure is sensed after the fuel supply cutoff valve. The PCC has an indicator and control for this valve. The VALVE OPEN/VALVE CLOSE pushbutton (C) is used to control the valve. Above it is the VALVE OPEN/VALVE CLOSED split indicator (D). It monitors the actual position of the valve, either open or closed. The VALVE OPEN/VALVE CLOSED indicator (E) is the last indicator. It also monitors valve status of the emergency JP-5 supply valve. This valve is held closed electrically. Upon loss of power to the normal fuel service system, the valve will open. This allows the GTs to run on JP-5 from a 350-gallon head tank.

ENGINE LUBE OIL.—The location of the engine lube oil section (J) of the engine 1B panel is shown on figure 10-6. Figure 10-13 is an enlarged view of this section. This section monitors the operation of the engine's lube oil supply and scavenge systems.

No control features are used in this section. It is only a monitor panel. It has a meter and seven indicators used to detect abnormal conditions of the lube oil system. The meter (A) displays the supply pressure of the lube oil. Associated with the meter is the LOW PRESSURE alarm indicator (B). This alarm sounds when the lube oil pressure drops to 15 psig. (Remember, an auto shutdown will occur if lube oil pressure drops to 6 psig.) The third component is the scavenge HIGH TEMP alarm indicator (C). This is a summary-type alarm that sounds when any of the five RTDs detect a temperature above 300 °F. When this alarm sounds, the operator should use one of the digital displays to identify which scavenge temperature is high. The scavenge LOW PRESSURE alarm (D) activates when scavenge pressure drops below 5 psig; the HIGH

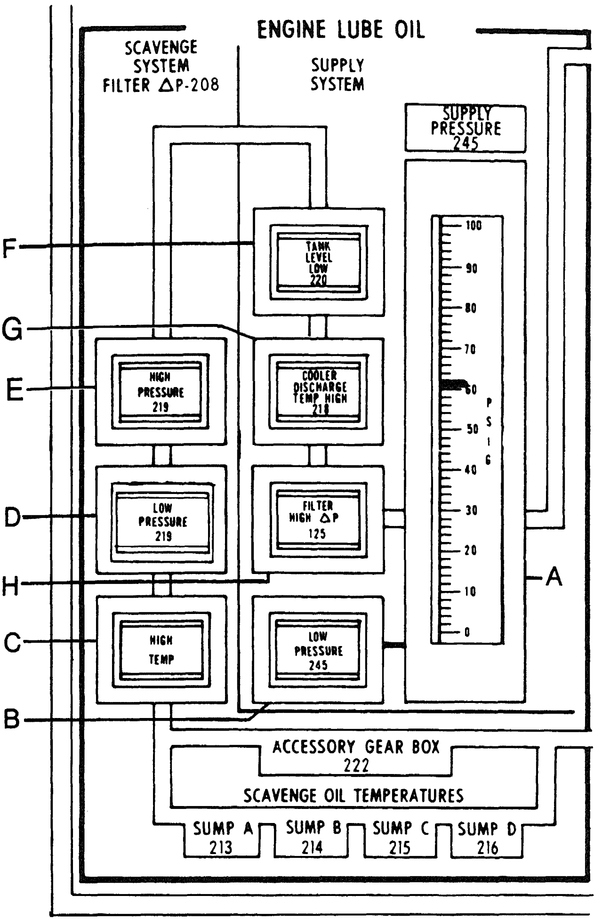

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Figure 10-13.—Engine lube oil section of the engine panel.

PRESSURE alarm (E) sounds when scavenge pressure is above 130 psig.

The TANK LEVEL LOW indicator (F) is used to monitor the level of the LOSCA lube oil tank. The alarm sounds when the tank level falls to 9.6 gallons. The COOLER DISCHARGE TEMP HIGH alarm (G) monitors the outlet temp of the oil leaving the LOSCA cooler. If the temperature of the oil exceeds 250 °F, this alarm will sound. The last indicator is the FILTER HIGH ΔP alarm (H). This alarm activates when the differential pressure across the lube oil supply filter exceeds 20 psid.

STOP.—The location of the stop section of the engine 1B panel is shown on figure 10-6. It is located above the lube oil section on the engine panel. Figure 10-14 is an enlarged view of this section.

The controls on the stop section are used to perform normal and manual stops. This section has three indicators, two pushbuttons, and a switch used for engine stopping. The first control, the NORMAL STOP pushbutton (A), is used to initiate a stop using the start/stop sequencer in the FSEE. This sequence, upon initiation, allows the engine to run at idle for 5 minutes. After 5 minutes it de-energizes the fuel shutdown valves causing the engine to shut down. This sequence may only be initiated if the engine is at idle. By advancing the throttle above idle, you can interrupt the normal shutdown any time before the fuel valve closure. The FUEL OFF indicator (B) is illuminated any time fuel manifold pressure is below 50 psi. The NORMAL STOP COMPLETE indicator (C), when illuminated, indicates $T_{5.4}$ is below 400 °F and fuel manifold pressure

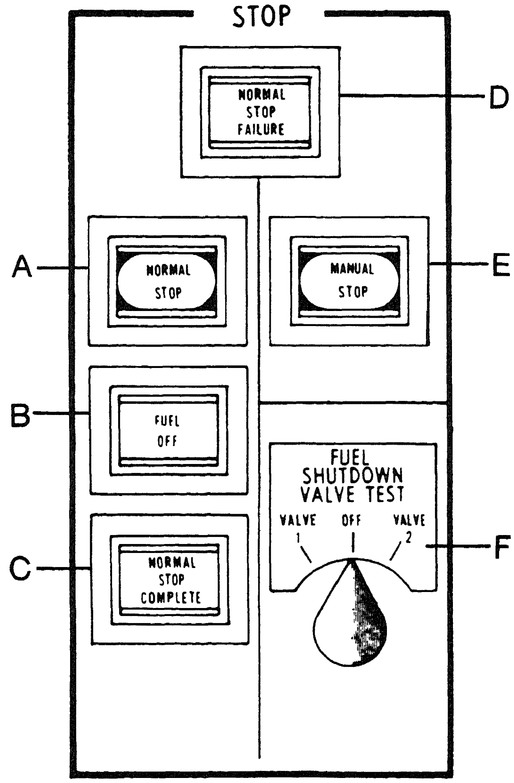

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Figure 10-14.—Stop section of the engine panel.

is less than 50 psi within 90 seconds after the completion of the 5-minute cooldown timer. Associated with this indicator is the NORMAL STOP FAILURE alarm (D). This indicator illuminates if, 90 seconds after the completion of the 5-minute cooldown timer, $T_{5.4}$ is above 400 °F or fuel manifold pressure is above 50 psig.

The other pushbutton in this section is the MANUAL STOP pushbutton (E). When it is depressed, the fuel shutdown valves are de-energized causing the engine to immediately stop. This stop should only be done after the engine has been allowed to cool down for 5 minutes to prevent engine damage. The three-position switch located below the MANUAL STOP pushbutton is the FUEL SHUTDOWN VALVE TEST switch (F). This switch is spring-loaded to the OFF position. Moving the switch to either the valve 1 or valve 2 position will shut the corresponding fuel shutdown valve and should stop the engine if the valve is operating properly. This is used to test the integrity of each of the fuel shutdown valves. Before moving this switch back to the OFF position, following PMS, depress the MANUAL STOP pushbutton to lock out both fuel valves. (NOTE: Remember to use the EOSS when doing any operation from the PCC.)

Fuel Oil Service System Panel

Located between the two engine panels is the fuel oil service system panel (figure 10-15). The panel is divided into two sections labeled 1 and 2. Each section has identical controls and indicators used to operate the fuel system on either number 1 or 2 tank, pump, heater, prefilter, or filter/separator. One tank and pump combination can supply both engines.

The level of a service tank may be monitored using the TANK LEVEL meter (A). Associated with this meter is a HIGH/LOW alarm (B) used to alert the operator when a tank is either full or needs refilling. The fuel oil tank suction and return valves may be operated from this panel by an OPEN/CLOSE pushbutton (C). The OPEN/CLOSED indicator (D) shows the status of both valves. This determines the tank that is supplying fuel to the fuel pump and where the excess fuel is returned. The valves may be opened and closed using the OPEN/CLOSE pushbutton (C). The pump suction valves (one per

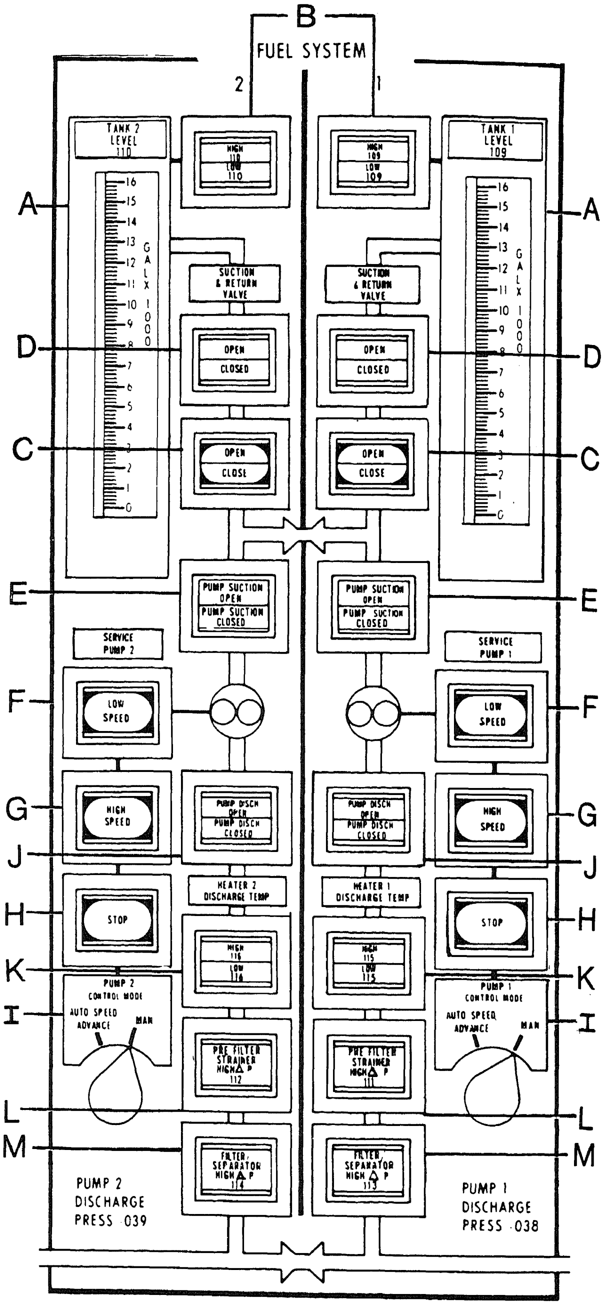

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Figure 10-15.—Fuel oil service system panel.

pump) are electrically interlocked with the pump start/stop pushbuttons and opened before the pump starts. Indication is provided at the PCC by the PUMP SUCTION OPEN/PUMP SUCTION CLOSED indicator (E).

Three pushbuttons and a control mode switch control the two service pumps. The three pushbuttons are labeled LOW SPEED (F), HIGH SPEED (G), and STOP (H). The CONTROL MODE switch (I) is used to set the pumps in the MAN (manual) mode or the AUTO SPEED ADVANCE mode. Each pump is a two-speed pump. In the manual mode the operator selects the speed of the pump (low or high) by depressing the proper pushbutton. In the automatic mode, a drop in fuel pressure will shift the pump from low to high. If low speed is again desired, the operator must shift the speed back to low. The pump discharge valve is equipped with a limit switch to show the actual position of the valves. This valve is operated manually at the valve.

The HEATER DISCHARGE TEMP HIGH/LOW alarm (K) is a split indicator alarm for high or low temperature. If the temperature of the fuel leaving the heater exceeds 110 °F, the high alarm sounds. Likewise, if the temperature drops below 60 °F, the low alarm sounds.

A fuel prefilter is used in the system to remove large particulate matter. If its ΔP exceeds 10 psid, the PREFILTER STRAINER HIGH ΔP alarm (L) activates. A second filter, called the FILTER/SEPARATOR, is used to separate out smaller particles and water. If this becomes clogged with a ΔP of 12 psid, the FILTER/SEPARATOR HIGH ΔP alarm (M) activates.

Gear Lube Oil Panel

The gear lube oil panel (figure 10-16) is used to control and monitor the flow of lube oil to the MRG.

The first indicator (A), SUMP LEVEL LOW, alerts the operator when the level of the MRG oil sump drops below 870 gallons. The indicator next to that is the STRAINER HIGH ΔP alarm (B). If the differential pressure across the lube oil strainer (actually mounted in the line after the pumps) exceeds 12 psid, this alarm activates.

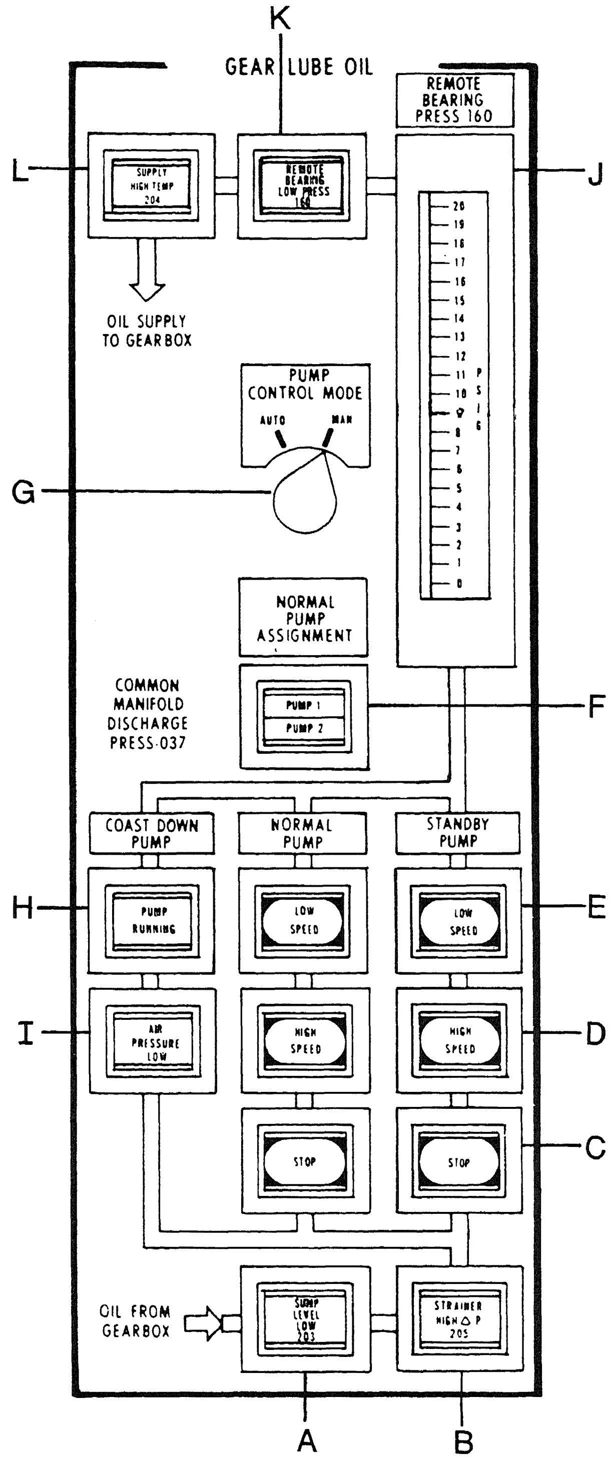

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Figure 10-16.—Gear lube oil panel.

Gear lube oil pump control is available from the PCC for the two motor-driven two-speed pumps. The pumps may be operated in either the manual or automatic mode. Normal and standby pump assignment is done by a switch on the lube oil pump controller in the engine room.

The speed control pushbuttons are used for manual speed control. The operator may use these pushbuttons in the manual mode to STOP (C), run in HIGH SPEED (D), or run in LOW SPEED (E) the two lube oil pumps. First the normal pump is selected (its selection is shown by the NORMAL PUMP ASSIGNMENT PUMP 1/PUMP 2 indicator (F)). Then the operator manually starts the selected pump to start the lube oil system. After the lube oil system is started, the operator may put the system in automatic by placing the PUMP CONTROL MODE switch (G) to AUTO. In the automatic mode, the pumps cycle up in speed in response to pressure decreases. If the pressure drops to 15 psig, the normal pump shifts from low to high speed. A drop in pressure to 13 psig causes the standby pump to start in low speed. A further decrease in pressure to 11 psig causes the standby pump to go to fast. When system pressure returns, the pumps must be manually cycled to lower speeds or off.

If the lube oil pressure drops to 9 psig, or if both electric pumps lose power, a third air-driven pump provides oil to the MRG. This pump is called a coastdown pump. It has a PUMP RUNNING indicator (H) on the PCC to show when it is running. The coastdown pump will only run if the shaft is turning. Also, it will stop if the lube oil pressure exceeds 15 psig. Another indicator, the AIR PRESSURE LOW indicator (I), alerts the operator when the air supply to the pump is low. It activates at 2700 psig.

The lube oil pressure is monitored at the PCC by monitoring the hydraulically most remote bearing pressure on the REMOTE BEARING PRESS meter (J). If the remote bearing pressure drops to 9 psig, the REMOTE BEARING LOW PRESS alarm indicator (K) activates. The lube oil temperature is also monitored. If it exceeds 130 °F, the SUPPLY HIGH TEMP alarm (L) sounds.

Propulsion Control Panel

The propulsion control panel (figure 10-17) is shown as a foldout at the end of this chapter. It

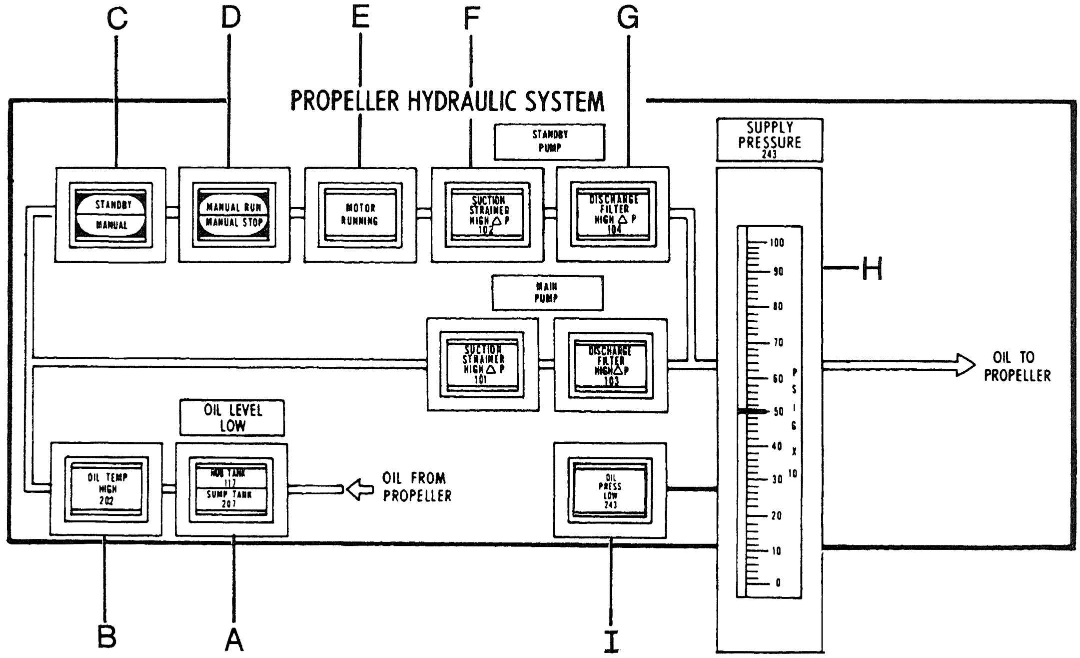

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Figure 10-18.—Propeller hydraulic system section of the propulsion control panel.

is one of the bottom panels of the PCC. This panel has the controls and indicators for the propeller hydraulic system, shaft speed and propeller pitch, MRG monitoring, and control transfer.

PROPELLER HYDRAULIC SYSTEM.—This section of the propulsion control panel has a meter, eight indicators, and two control pushbuttons. These are used to operate the hydraulic system of the controllable pitch propeller. Figure 10-18 is an enlarged view of this section.

The HUB TANK/SUMP TANK split indicator (A) monitors the oil level of the sump and head tanks. If the level in the head tank falls to 35 gallons, the HUB TANK indicator illuminates. If the sump tank level drops below 425 gallons, the SUMP TANK indicator illuminates. The next indicator (B), OIL TEMP HIGH, activates to alert the operator that the oil temperature in the system has exceeded 160°F.

Normally, the hydraulic pressure is supplied to the system by the pump that is driven by the reduction gear (attached gear pump). When this pump cannot provide the proper pressure, it must be augmented by the standby motor-driven pump. Two control pushbuttons are used to operate the motor-driven pump. The STANDBY/MANUAL pushbutton (C) sets the mode of operation. In the standby mode, when the shaft speed drops to about 105 SRPM, the motor-driven pump starts. When the pushbutton is placed in the manual mode, the motor-driven pump must be started by the operator. The operator uses the MANUAL RUN/MANUAL STOP pushbutton (D). When the motor-driven pump is running, the MOTOR RUNNING indicator (E) illuminates. Both pumps have suction strainers in the pump suction lines and discharge filters in the pump discharge lines.

This section of the panel has indicators to alert the operator when the discharge filters and the suction strainers become clogged. If the differential pressures of the suction strainers reach 7 in. Hg, the SUCTION STRAINER HIGH ΔP alarm (F) activates. If the discharge filter ΔP exceeds 40 psid, the DISCHARGE FILTER HIGH ΔP alarm (G) activates. A meter (H) monitors the CPP hydraulic supply pressure. Associated with this meter is the OIL PRESS LOW indicator (I). If supply oil pressure drops to 40 psig, this alarm sounds.

ENGINE ORDER TELEGRAPH.—Located below the propeller hydraulic section, is the EOT (figure 10-19). This is used to relay engine orders from the bridge to the PCC. When the bridge orders a change of speed, one of the pointers in the EOT will point to the requested speed. The PCC operator, to acknowledge the order, moves the other pointer to match the bridge pointer. This is done using the knob (A) below the EOT. If the pitch of the propeller and the EOT indicate opposite directions (ahead and astern), the EOT WRONG DIRECTION alarm bell (B) sounds.

SHAFT PERFORMANCE MONITORING.—Located to the right of the propeller hydraulic system panel are the indicators used to monitor the propeller shaft performance. This

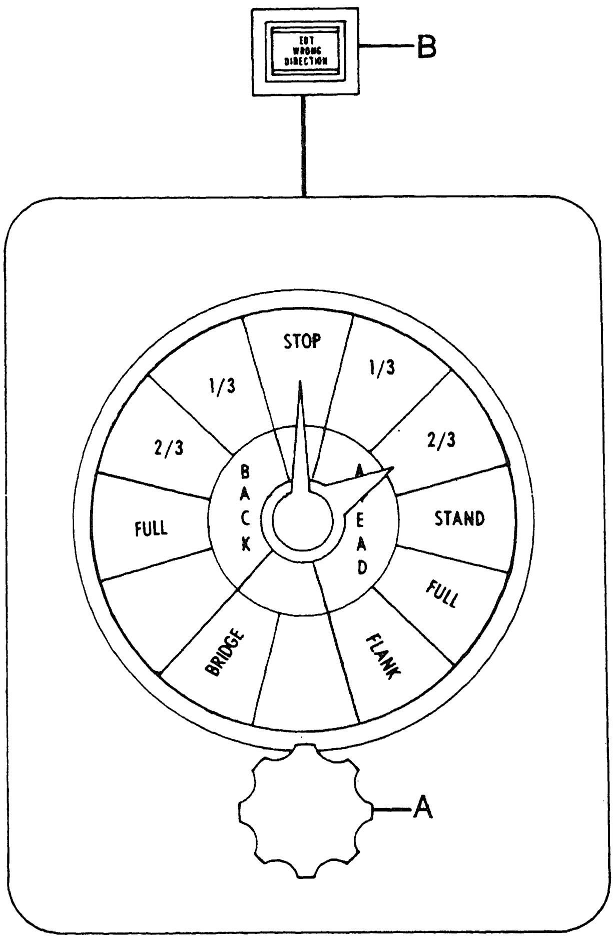

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Figure 10-19.—Engine order telegraph.

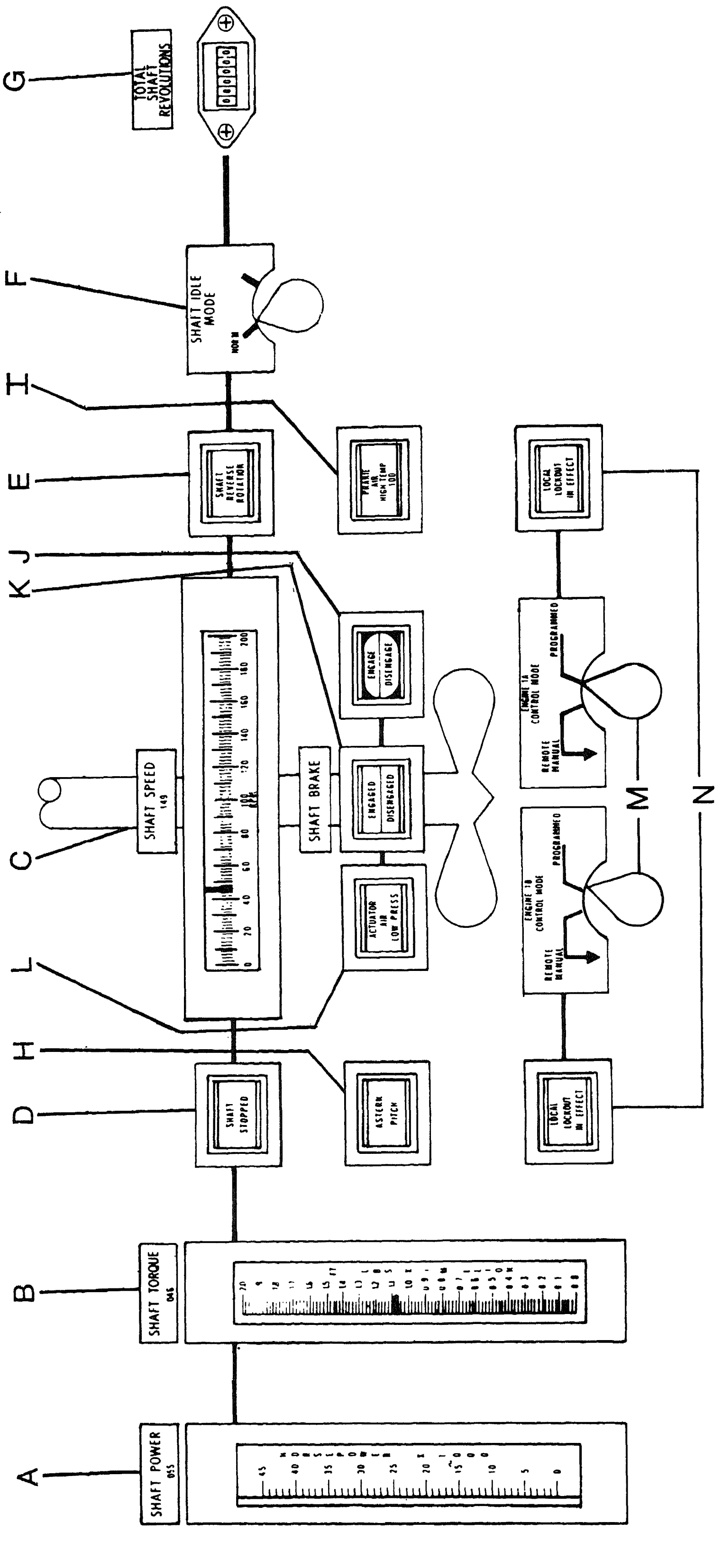

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Figure 10-20.—Shaft performance monitoring section.

section (figure 10-20) has three meters used to monitor shaft speed, torque, and horsepower; shafting indicators; shaft brake controls; and indicators and engine mode select controls.

The SHAFT POWER meter (A) displays shaft power. It displays in horsepower and receives its input from the processor. The next meter (B) is used to display SHAFT TORQUE. This parameter is also sent from the processor and displays in ft-lb. The third meter (C) is a horizontal edgewise meter that shows SHAFT SPEED. Associated with the shaft speed meter is the SHAFT STOPPED indicator (D). When illuminated, this indicator shows shaft stopped when it is rotating less than 1/5 rpm. On the other side of the shaft speed meter is the SHAFT REVERSE ROTATION indicator (E). When this indicator is illuminated, the propeller shaft is rotating in the reverse direction. Next to this indicator is the SHAFT IDLE MODE switch (F). This switch has only one position (NORM). It is not used. To the right of the switch is the TOTAL SHAFT REVOLUTIONS counter (G). This counter shows total shaft revolutions of the propeller.

The ASTERN PITCH indicator (H) shows when the pitch of the propeller is in the astern direction. The PRAIRIE AIR HIGH TEMP indicator (I) is an alarm indicator that activates when prairie air temperature exceeds 135°F.

The shaft brake section is located below the shaft speed meter. One control pushbutton and two indicators are used to display conditions of the shaft brake. The shaft brake ENGAGE/DISENGAGE pushbutton (J) is used to apply and release the shaft brake. It may only be applied if the following conditions are met.

- Shaft speed is less than 75 rpm.
- Throttles are at idle.
- Pitch is at zero.
- Only station in control of the engine(s) may apply shaft brake.

When these permissives are met, the control pushbutton activates the shaft brake. If one of these permissives is lost, the shaft brake will release. The shaft brake indicator (K) will show the actual status of the shaft brake, either ENGAGED or DISENGAGED. The shaft brake ACTUATOR AIR LOW PRESS alarm indicator (L) alerts the operator if the air pressure used to operate the shaft brake drops below 1150 psig.

Below the shaft brake section are two engine control mode rotary switches (M), one per engine. These switches are used to place the engines in either PROGRAMMED or REMOTE MANUAL mode. The remote manual mode is used when starting or stopping a GT. It is also an alternate method of operating the throttle/pitch combination. Programmed control is the normal operating throttle mode used after the engine is started. These modes are discussed later in this chapter when we cover the throttle controls.

MODE SETTING AND REDUCTION GEAR MONITORING.—To the right of the shaft performance section is the area of the propulsion control panel used to set propulsion modes, programmed control location, and to monitor the reduction gear bearings. This area is shown in figure 10-21.

The first control (A) is used only in programmed mode and is labeled PROPULSION MODE. This control has two positions, POWER and SPEED. When placed in the POWER position, the processor automatically adjusts the pitch and PLA commands to provide a consistent load on the engine. To do this, the processor uses the torque computer. At powers above full pitch, an almost linear relationship between the position of the programmed control lever and steady state shaft rpm exists. In the power mode, the engine or engines are kept at a steady power level. In some sea states and/or under some maneuvering conditions, the shaft rpm will vary above or below a normal value. This variation in the power mode is normal and expected.

The other position of the switch is the SPEED mode. When operating in the speed mode, the processor automatically adjusts the propeller pitch signals and the PLA actuator signals to provide a constant propeller shaft rpm. To do this, the processor uses built-in power schedules and propeller shaft rpm feedback. The programmed control lever gives the operator fine control of shaft rpm. The operator can make careful adjustments to ship's speed in relatively calm seas and during alongside evolutions.

Just to the right of the propulsion mode switch is the ROUGH WEATHER DAMPING switch (B). This is an ON/OFF switch. This switch is only

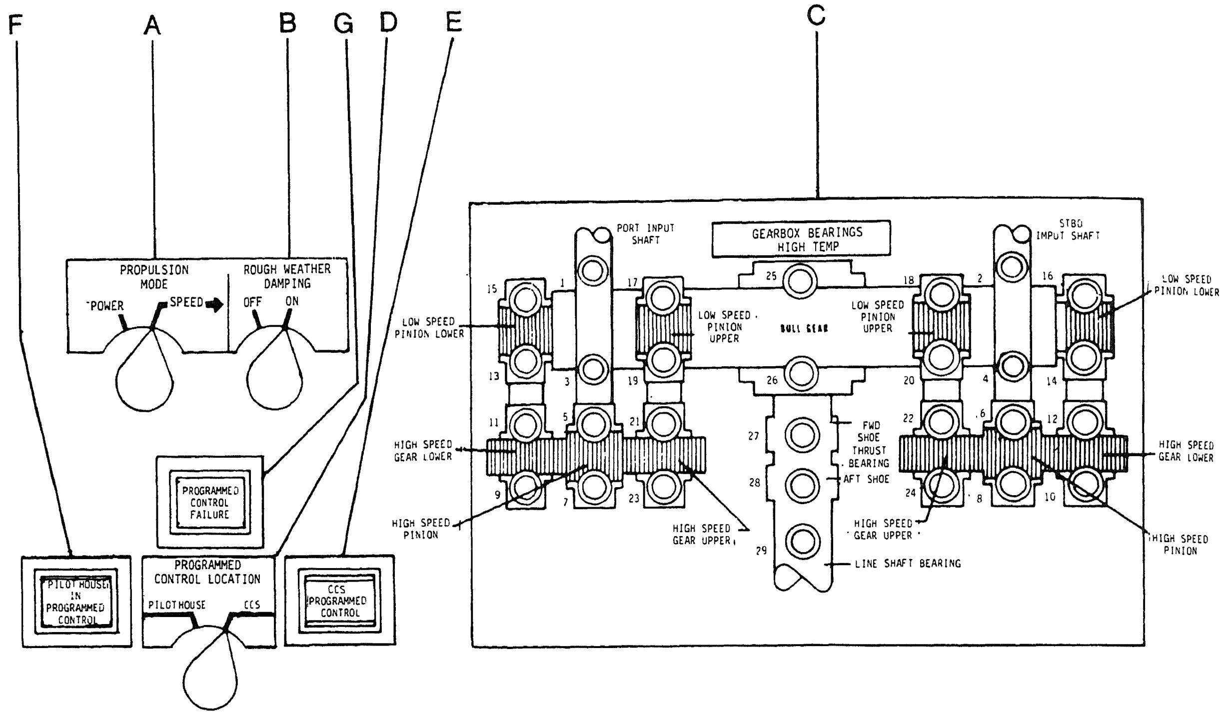

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Figure 10-21.—Mode setting and reduction gear monitoring section.

operative when operating in programmed control mode and in the speed mode. When the rough weather damping circuit is used, the processor attempts to even out PLA actuator command signals during rough sea conditions. This is to reduce hunting (fluctation) of the propeller shaft rpm.

The next section has the reduction gear bearing high temperature indicators (C). There are 29 indicators, one for each bearing in the MRG. Associated with each indicator is a number, 1 to 29; placing zeros in front of these numbers makes three-digit numbers. You will then have the DDI number for that bearing. If you use these numbers as reference numbers, 1 to 26 are for the babbitt bearings; the sensors are in the babbitt and are sensing babbitt temperature. Numbers 27 and 28 are for the thrust bearings; number 29 is for the line shaft bearing.

Below the propulsion mode and rough weather damping switches is a two-position PROGRAMMED CONTROL LOCATION switch (D). It determines the location of the programmed control. The programmed control location rotary switch, when positioned to CCS, shows that the control of the programmed mode is at the PCC. The other switch position is PILOTHOUSE. With the switch in this position, control of programmed control is at the pilothouse (SCC).

Associated with these switches are three indicators. On the right-hand side is the CCS PROGRAMMED CONTROL indicator (E). When this indicator is illuminated, the control of the propulsion system is at the PCC. On the left side of the switch is the PILOTHOUSE IN PROGRAMMED CONTROL indicator (F). When this indicator is illuminated, the control of the propulsion system is at the pilothouse. Directly above this switch is the PROGRAMMED CONTROL FAILURE indicator (G). This indicator illuminates when the processor has failed or has not made a complete cycle and has stopped. If this occurs, the processor will have to be restarted. During this time period, the DDIs and the loggers may not be operating properly.

SHAFT CONTROL.—The lower section of the propulsion control panel (figure 10-22) has

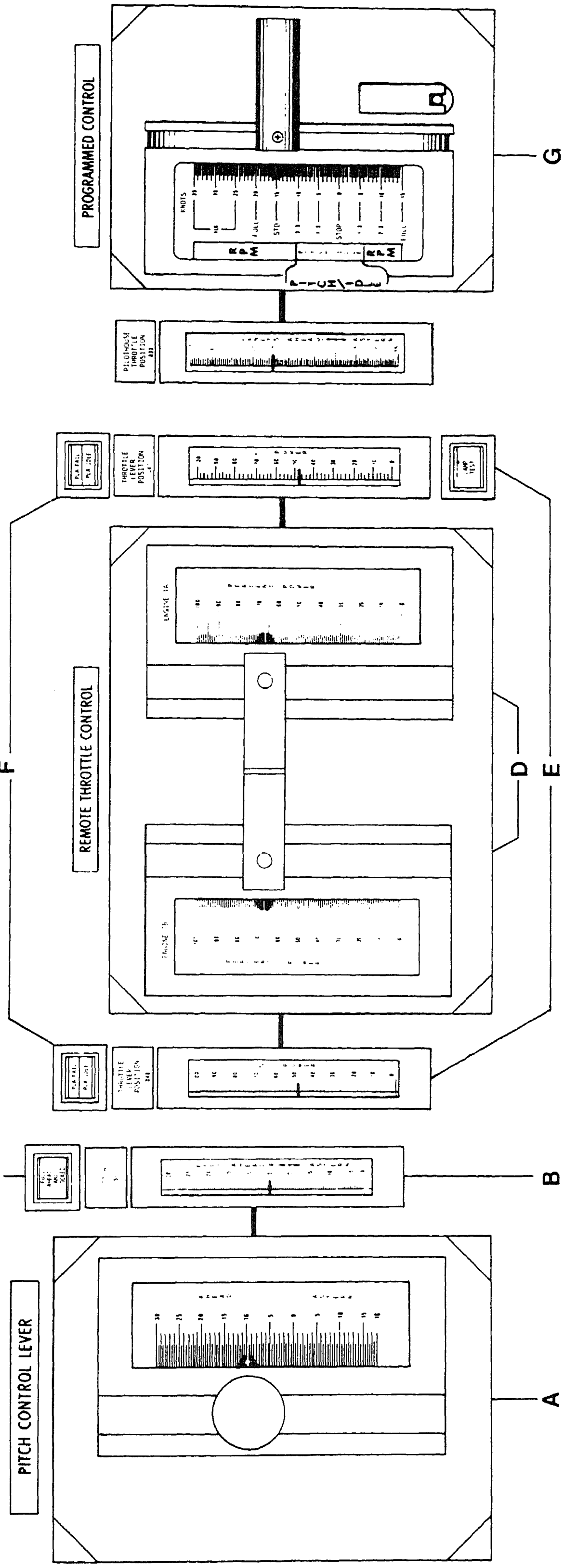

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Figure 10-22.—Shaft control.

the levers and indicators used to operate and monitor the speed and pitch of the propeller shaft.

The lever at the left is the PITCH CONTROL LEVER (A). It controls propeller pitch in the remote manual mode. To the right of this lever is the PITCH meter (B). It shows the actual pitch position. Above this meter is the FULL AHEAD AND LOCKED indicator (C). This indicator illuminates when the pitch of the propeller is full ahead and mechanically locked.

The next two levers (D) are for controlling the speed of the GGs, one lever for each GG. These levers can be locked together so that when the engines operate together, their speed will be the same. On either side of the REMOTE THROTTLE CONTROL levers are meters for the THROTTLE LEVER POSITION (E), one for each engine. The meters are always showing the position of the throttle in percentage of power. This is regardless of how the engine or engines are being controlled. Above each meter is a split-legend indicator (F). The upper half reads PLA FAIL, the lower half reads PLA IDLE. When the PLA IDLE indicator illuminates, the throttles are setting at the idle position; the idle position is 13 degrees of PLA. When the PLA FAIL indicator illuminates, the throttle is at some position less than 13 degrees of PLA.

The last lever to the right is the PROGRAMMED CONTROL lever (G). This lever is only functional when the engine control mode switch of either engine is in the PROGRAMMED position. The programmed control mode is the primary mode of operation. The propulsion system can be operated in the programmed control mode using either one or both GTEs.

The programmed control lever, through the processor, controls the propeller blade pitch and the speed of one or both GTEs. The operator positions the programmed control lever. Then the processor senses the position of the programmed control lever. It computes the correct propeller blade pitch command signals and correct PLA actuator command signals. The propeller blade pitch command signals, developed by the processor, are transmitted to the electrohydraulic servo valve to position the pitch of the propeller blade. The PLA actuator command signals, developed by the processor, are transmitted to the FSEE for control of the engines. With one or both engines at idle, the propeller blade pitch at zero, and the shaft rotating, there is neither ahead nor astern thrust to the ship. Pushing the programmed control lever forward (away from the operator) changes the propeller blade pitch; this causes the ship to move forward. Pulling the programmed control lever back from the zero position (toward the operator) reverses the propeller blade pitch; this causes the ship to move astern. Changing the propeller blade pitch from zero puts a load on the propeller shaft, the reduction gear, and the PT(s).

As the propeller blade pitch increases, the processor automatically adjusts the fuel flow to the GG. This is to maintain the propeller shaft rpm as required by either the power mode or the speed mode. Once full propeller blade pitch is achieved, further advances to the programmed control lever increase propeller shaft rpm. To decrease the ship's speed, the operator moves the programmed control lever back toward the zero position; this reduces propeller shaft rpm and then propeller blade pitch.

CAUTION

The programmed control mode must not be used when the propeller blade pitch is being controlled from the oil injection box or when it has been locked in the full-ahead position. This is because no input has been made to the processor that the propeller blade pitch is being operated manually or has been locked in the full-ahead position; the processor would still be computing and transmitting propeller blade pitch commands.

Fuse Panels

The fuse panel (figure 10-23) is located just to the left of engine start panel 1B. This panel has fuses for the seawater cooling, fuel system, gear lube oil, propeller hydraulic pump, and for transducers-24 VDC. When a generated command does not appear to be received, troubleshooters should begin by checking the associated fuses. The only time voltage is applied across the fuse is when a command is transmitted.

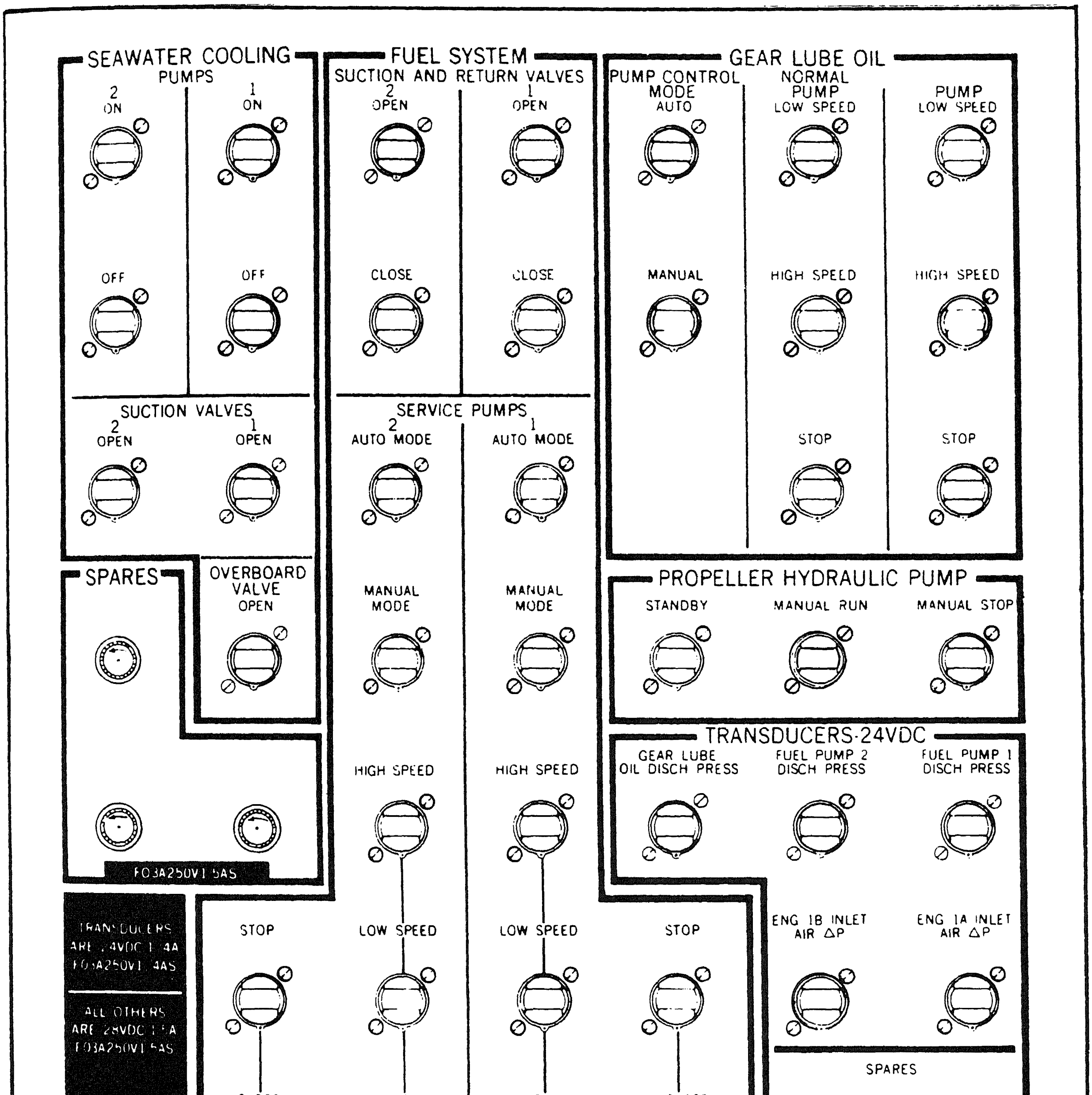

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Figure 10-23.—PCC fuse panel.

On the right-hand side of engine start panel 1A is the status and fuse panel (figure 10-24). On the fuse part are the 28 VDC fuses for the power being fed to the panels; the other fuses are for the 115 VAC being fed other components as indicated on the panel.

On the upper left-hand side are three status indicators for the PCC. The first indicator is for OVERTEMP of the console cabinet internal temperature. This is set at 160°F. The second indicator is a split-legend indicator. The upper half is for 28 VDC UPS AVAILABLE. This indicator illuminates when 28 VDC UPS from the power supply enclosure assembly (PSEA) is available. The lower half of the indicator, HEATERS ON, illuminates when the heaters are energized. It will not be illuminated during a lamp test. The last indicator under the PCC section of this panel is the MAINT MODE indicator. It illuminates when the operate/test switch of the

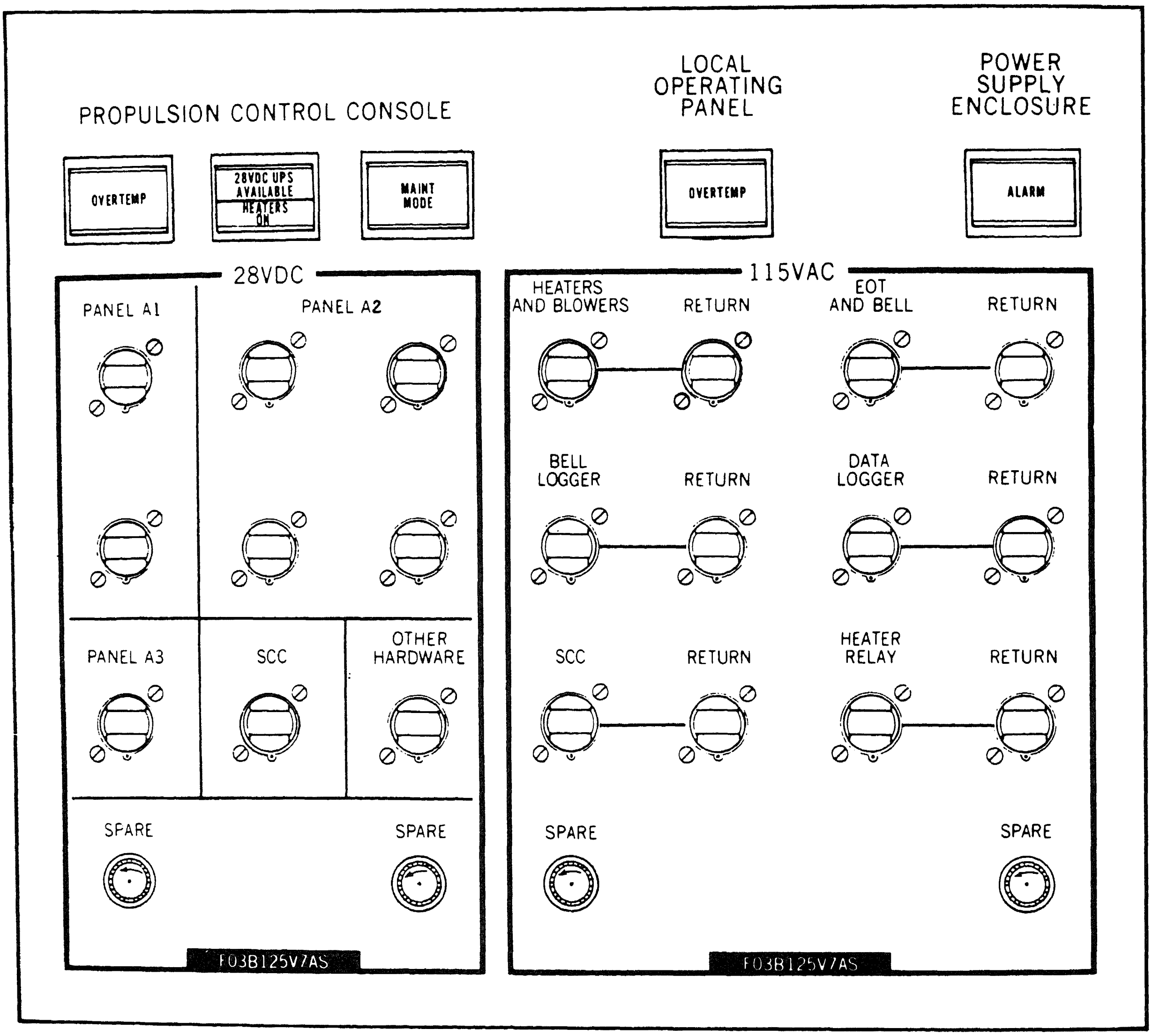

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Figure 10-24.—PCC status and fuse panel.

processor on the maintenance panel is in the test position. The only time this should be illuminated is when a maintenance person is working on the system. If this is illuminated, the DDIs and programmed control may or may not be operating. The next indicator is for the LOP OVERTEMP. This indicator illuminates when the internal temperature is greater than 160°F. The last indicator on this panel is for the power supply enclosure and the indicator reads ALARM. This alarm illuminates when a monitored voltage has fallen below its set point or the cabinet temperature is high.

Operational Adjustments Panel

The last panel on the PCC is the operational adjustments panel (figure 10-25). It is located behind the second door from the left in the front of the PCC. The operational adjustments panel is subdivided into four sections. From left to right these sections are engines, shaft turns, pitch trim, and time set.

ENGINE GROUP.—This group has six recessed screwdriver adjustable potentiometers. They provide calibration parameters for engine and propeller subroutines of the software program.

The top section is the BIAS section; in this section are two adjustment potentiometers. These are used to adjust the output of each engine to 20,500 hp when the engines are operating in the power mode in programmed control with the programmed control lever set at full power.

The RPM MODE section also has two adjustment potentiometers; both of the potentiometers are associated with operating the plant in programmed control with the propulsion mode switch in the speed position. The upper potentiometer is for adjusting the LOOP TIME CONSTANT. In other words, it provides an adjustment to change the response time of the subroutine when the engine is operating in the RPM (speed) MODE. The lower potentiometer is for adjusting the LOOP GAIN CONSTANT. It provides an adjustment to change the amount of feedback used in computing the throttle commands in the RPM MODE.

The last section in the engine group is for the WASH SPEED. It has two indicators; the upper potentiometer is for setting the upper speed limit at which the starter will be turned off during a water wash. The lower potentiometer is for setting the lower limit at which the starter will be turned on during a water wash.

SHAFT TURNS GROUP.—The LOGIC UPDATE section has six thumbwheels. They are used to update the logic used by the processor to print the total number of shaft turns on the bell loggers. Below these thumbwheels is a pushbutton switch. When depressed, it loads the value dialed on the logic update thumbwheels into the applicable registers. Located next to the logic update is the COUNTER portion. It has two

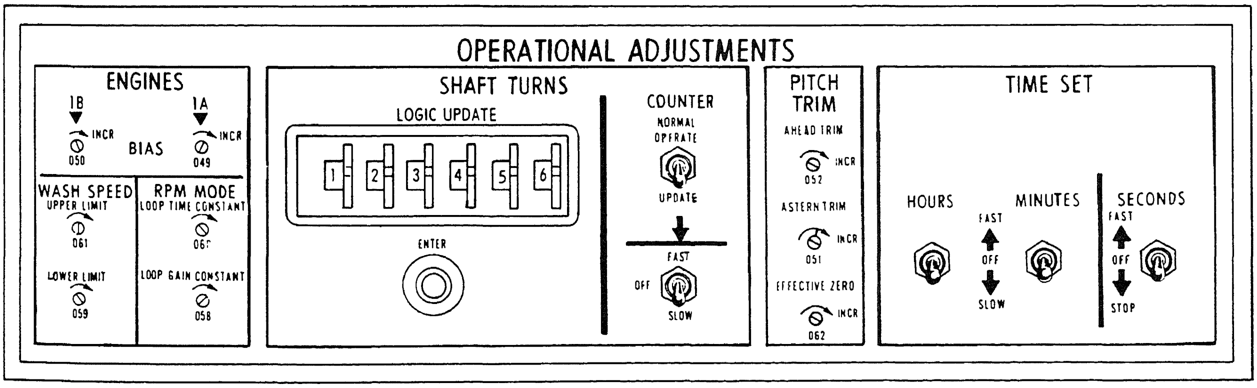

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Figure 10-25.—Operational adjustments panel.

toggle switches. Both switches are spring loaded. The upper switch is used to control logic that drives the mechanical counter. When the switch is at rest (NORMAL OPERATE) position, the counter (on the PCC panel) will count as a function of the shaft revolution sensor. When held in the UPDATE position, the counter will count as a function of the FAST/OFF/SLOW (lower) toggle switch.

The FAST/OFF/SLOW spring-loaded toggle switch is enabled when the NORMAL OPERATE/UPDATE toggle switch is in the update position. The switch position at OFF (middle or rest) will not allow the counter to count. When held in the FAST (upper) position, the counter will count at the rate of ten revolutions per second. When held in the SLOW (lower) position, the counter will count at the rate of one revolution per second.

PITCH TRIM.—The next section is the PITCH TRIM section. This section has three recessed screwdriver adjustable potentiometers. They allow compensation between the propeller pitch subroutine of the software program and the equipment that performs the propeller pitch adjustment. The top potentiometer is for AHEAD TRIM. It is adjusted to give 23.5 feet pitch, when operating in programmed control, with a command equal to or greater than ahead 2/3. The middle potentiometer is for ASTERN TRIM. It is adjusted to give 14.7 feet pitch, when operating in programmed control, with a command equal to or greater than back 1/3. The bottom potentiometer is for EFFECTIVE ZERO. It is used to adjust pitch to zero thrust, when operating in programmed control, with a command of stop.

TIME SET.—The last section of this panel is the TIME SET section. It is used by the operator to set the clock on the demands panel. It has three spring-loaded toggle switches. From left to right the toggle switches are labeled HOURS, MINUTES, and SECONDS. These switches are three-position toggle switches. The center position is labeled OFF. In this position the clock will display and count automatically. Moving the HOURS switch up or to the FAST position and holding it there causes the hour portion of the clock to increment at the rate of 10 hours per second. Moving the switch to the lower or SLOW position and holding it there causes the clock to update at the rate of 1 hour per second. The middle switch is for MINUTES. Its positions are also labeled FAST/OFF/SLOW. With the switch in the OFF (middle or rest) position, the clock will count automatically. Moving and holding the switch in the up or FAST position causes the minute portion of the clock to update at the rate of 1 minute per second. The last switch is for SECONDS. This switch in the OFF (middle or rest) position allows the clock to operate automatically. Moving the switch to the up or FAST position causes the clock to update at the rate of 10 seconds per second. Moving the switch to the down or STOP position stops the entire clock.

ELECTRIC PLANT CONTROL CONSOLE

The electric plant control console (EPCC) is located in the CCS. It is a processor controlled console used to monitor the SS diesel generators (SSDGs), SS switchboards, and the other features of the electric plant. The EPCC operator is normally the only watch stander on the ship's electric plant.

This section provides a limited discussion of the systems that interface with the EPCC. The description of the components within these systems is contained in the individual equipment technical manuals and other chapters of this RTM.

The EPCC and the systems controlled and monitored are located within the CCS and auxiliary machinery rooms No. 1, 2, and 3, the switchgear room, and the engine room.

EPCC PHYSICAL ARRANGEMENT

The EPCC (figure 10-26) contains indicating lights, meters, and alarm. They provide the status of the equipment being monitored. The EPCC has pushbutton indicator switches to provide equipment control.

The indicators and switches on the EPCC are located on nine panels: engine fuel systems (panel A-1), supervisory control status/parameters/synchronization/paralleling (panel A-2), console power status/console-vital power feeder circuit

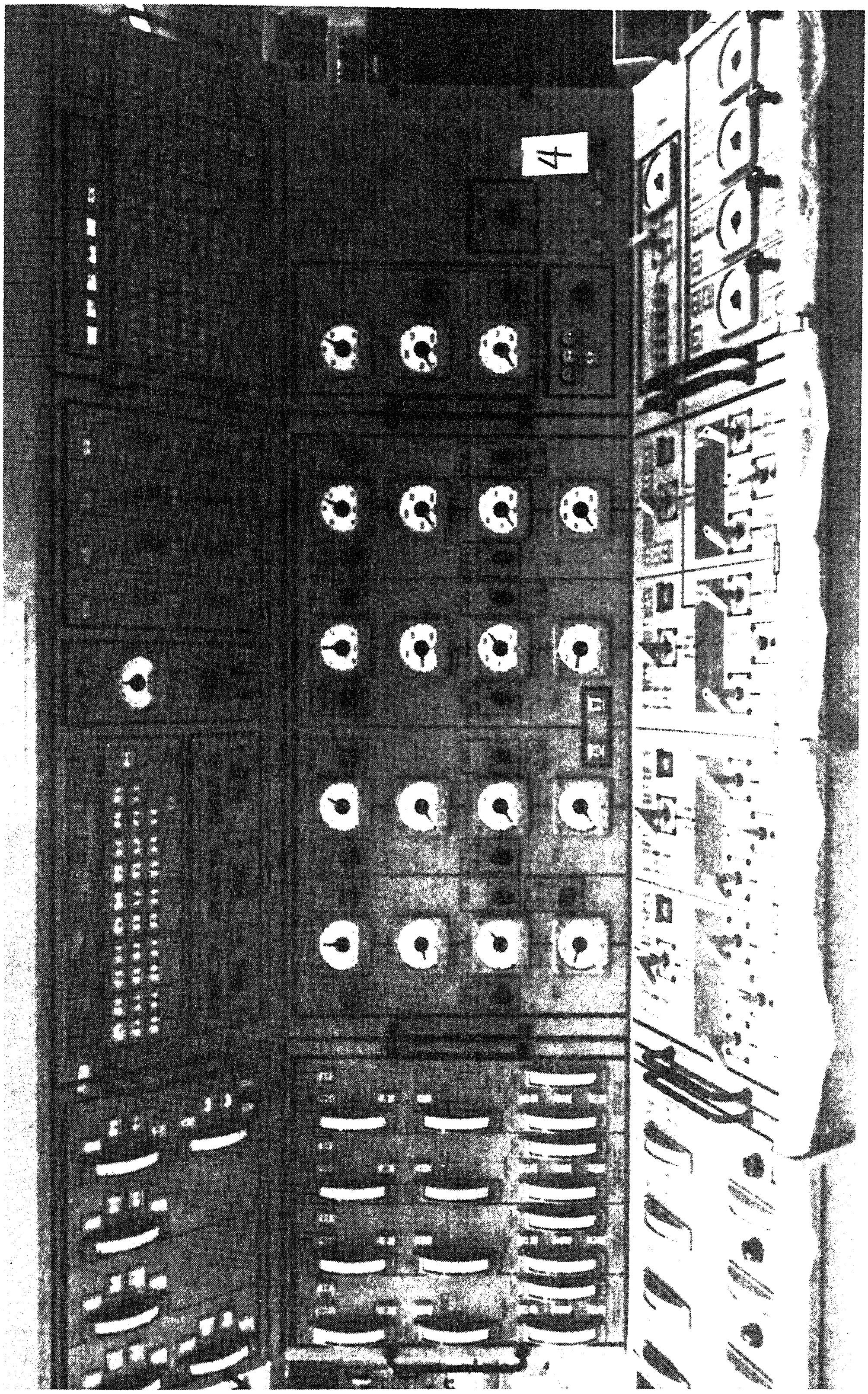

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Figure 10-26.—Electric plant control console.

breaker status (panel A-3), SSDG (panels A-4 and A-7), SSDG output and distribution (panels A-5 and A-8), system output monitor/ground status test/generator 4 voltage control (panel A-6), and shore power/generators (panel A-9). The lower portion of the EPCC contains three fuse panels.

The primary function of the EPCC is to monitor and automatically control the operation of the diesel generators and various auxiliary systems. The automatic function of the EPCC includes a supervisory control system (SCS) to avoid conditions that will result in power interruption of the electric plant. Also, the EPCC provides remote manual control of the electric plant.

NOTE: In automatic operation, the EPCC does not provide normal automatic control of load adjustment, voltage or frequency adjustment, or matching of generator capacity to that of the load. The only automatic operation of the EPCC is by the SCS. This is effective only when the SCS mode selector switch is in AUTO mode and only in response to a malfunction.

Pushbutton Switches

There are two types of pushbutton switches on the EPCC; alternate action and momentary action. The switches are backlighted to show the position of the switch. All emergency stop pushbuttons are illuminated red when actuated. The alternate action switches are illuminated green in both positions.

A delay may occur between actuation of a pushbutton switch and the illumination of its corresponding status indicator. This results when some physical movement of the component must occur (for example, a valve stem moving from the closed to the open position or vice versa).

Edgewise Meters

The edgewise meters provide continuous monitoring of a number of critical system component parameters associated with the diesel engines. The analog signal transmitted from the equipment is read in engineering units.

Dial-Type Meters

Dial-type meters are provided for all electrical parameters. These include voltage, frequency, current, kilowatt, and mechanical parameters for the generator such as stator temperature. Dial-type meters for electrical parameters are energized directly from their respective transformers on the switchboards without any intermediate conditioning circuits.

Local and Remote Operation

The EPCC is the remote operating station for SSDG1, SSDG2, and SSDG3 and their respective SS switchboards 1S, 2S, and 3S. The EPCC is the only operating position for the No. 4 generator and the SS switchboard 4S.

The SS switchboards 1S, 2S, and 3S are the local operating positions for their respective portions of the plant. Control of each portion of the plant is transferred from the SS switchboards 1S, 2S, and 3S to the EPCC by a local/remote control transfer located on these switchboards.

A local/remote control switch in auxiliary machinery room No. 3 transfers start/stop control of SSDG4 to its local control panel.

CAUTION

ANY diesel can be stopped locally at the SSDG control panel irrespective of the position of its associated local/remote transfer switch.

Three green-colored LOCAL CONTROL/REMOTE CONTROL indicator lights are provided on the console. They indicate the status of the control transfer switches.

Control of equipment providing auxiliary service to the electric plant, such as fuel and saltwater service valves, is transferred by switches located on their controllers. Status of these transfer switches is not provided on the EPCC.

ENGINE FUEL SYSTEM PANEL

The engine fuel system panel A-1 (figure 10-27) displays the liquid levels of six engine fuel tanks. It has high- and low-level alarms,

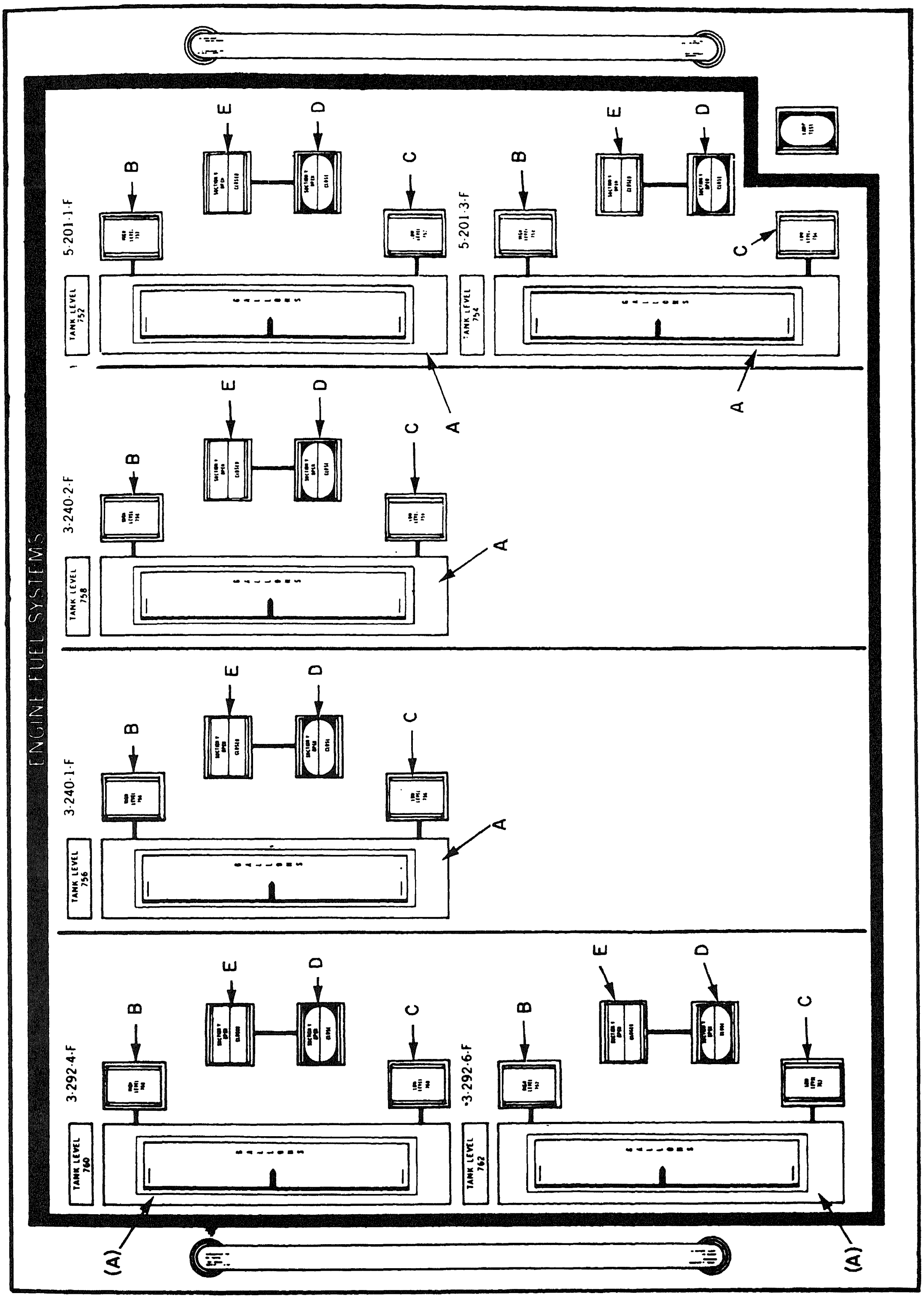

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Figure 10-27.—Engine fuel system panel.

pushbutton switch controls, and position indicators for associated fuel suction valves.

The liquid levels within fuel tanks 5-201-1-F, 5-201-3-F, 3-240-1-F, 3-240-2-F, 3-292-4-F, and 3-292-6-F are always displayed on the EPCC on edgewise meters (A). The signal is derived from the local tank level indicator system. Alarm circuits are energized when predetermined upper (B) and lower (C) limits are reached.

SUCTION V OPEN/CLOSE pushbuttons (D) are provided for six fuel suction valves, one for each of the six fuel tanks. The indicator lights in the pushbuttons show the open or closed status of the pushbutton switch as ordered by the console operator. The SUCTION V OPEN/CLOSED indicator lights (E) are provided to indicate the actual open or closed status of each of the six solenoid-operated valves.

Fuel tanks serve diesel generators as follows.

Fuel tanks 5-201-1-F and 5-201-3-F—SSDG1

Fuel tanks 3-240-1-F and 3-240-2-F—SSDGs 2 and 3

Fuel tanks 3-292-4-F and 3-292-6-F—SSDG4

The valves are located in the three auxiliary machinery rooms. When the LOCAL/REMOTE switch on each of the valve controllers is in the local position, control of the valves is at the valve. When the LOCAL/REMOTE switch is at the remote position, control is at the EPCC. A transducer in the local tank level indicator system provides signals to the console for driving meters displaying tank levels. This data is also used for demand displays. Console logic circuitry, incorporating a 10-second delay, activates both high-level and low-level alarm indicators.

SSDG PANEL (A-4)

The A-4 panel (figure 10-28) displays diesel engine fuel manifold pressure, engine speed, lubricating oil pressure, and lubricating oil temperature.

SSDG Fuel Service Systems

An engine-driven fuel supply pump on each diesel engine delivers fuel from the associated fuel tank(s) to the engine. Unconsumed fuel is routed through a cooler and back into the supply line.

Pressure transducers are used at discharge of the fuel supply pumps and in the fuel manifolds. Supply pump discharge pressures are available at the EPCC as demand displays. Signals for low pressures (failure) in the manifolds are derived by console logic circuitry from the analog signals for the MANIFOLD PRESS meter (A) and activate FUEL PRESSURE FAILURE alarms (B). The FUEL PRESSURE FAILURE alarms are automatically inhibited without an engine run signal and when PRIME MOVER STOP pushbuttons are depressed.

The RTDs are used in the fuel return lines. Fuel return line temperatures are available as demand displays. Signals for high temperatures in the return lines come from the analog signal for the demand displays by EPCC logic circuitry. They activate FUEL RETURN HIGH TEMPERATURE alarms (C).

Enclosure Fire

A fire in the acoustic enclosure surrounding each diesel generator set is detected by UV flame detectors located in the enclosure. The flame detectors provide a signal to a signal convertor. The signal convertor in turn, provides a signal to the EPCC for the ACOUSTIC CELL FIRE WARNING alarm (D). A temperature actuated switch actuates the ship's fire alarm system indicator on the DCC and IC panel interface in damage control central. NOTE: This alarm does not shut down the SSDG or release Halon.

Engine Speed

Diesel engine speed is measured by a PMA mounted on the aft end of the generator rotor. The PMA provides a frequency output proportional to engine speed. At the EPCC the signal is used to drive an ENGINE SPEED edgewise meter (E). The data is also available as a demand display. This signal is also used to enable alarms that are inhibited by the PRIME MOVER STOP pushbutton.

The ENGINE TRIP alarm (F) indicates that the diesel engine has been automatically shut down either by the overspeed trip, by low lube

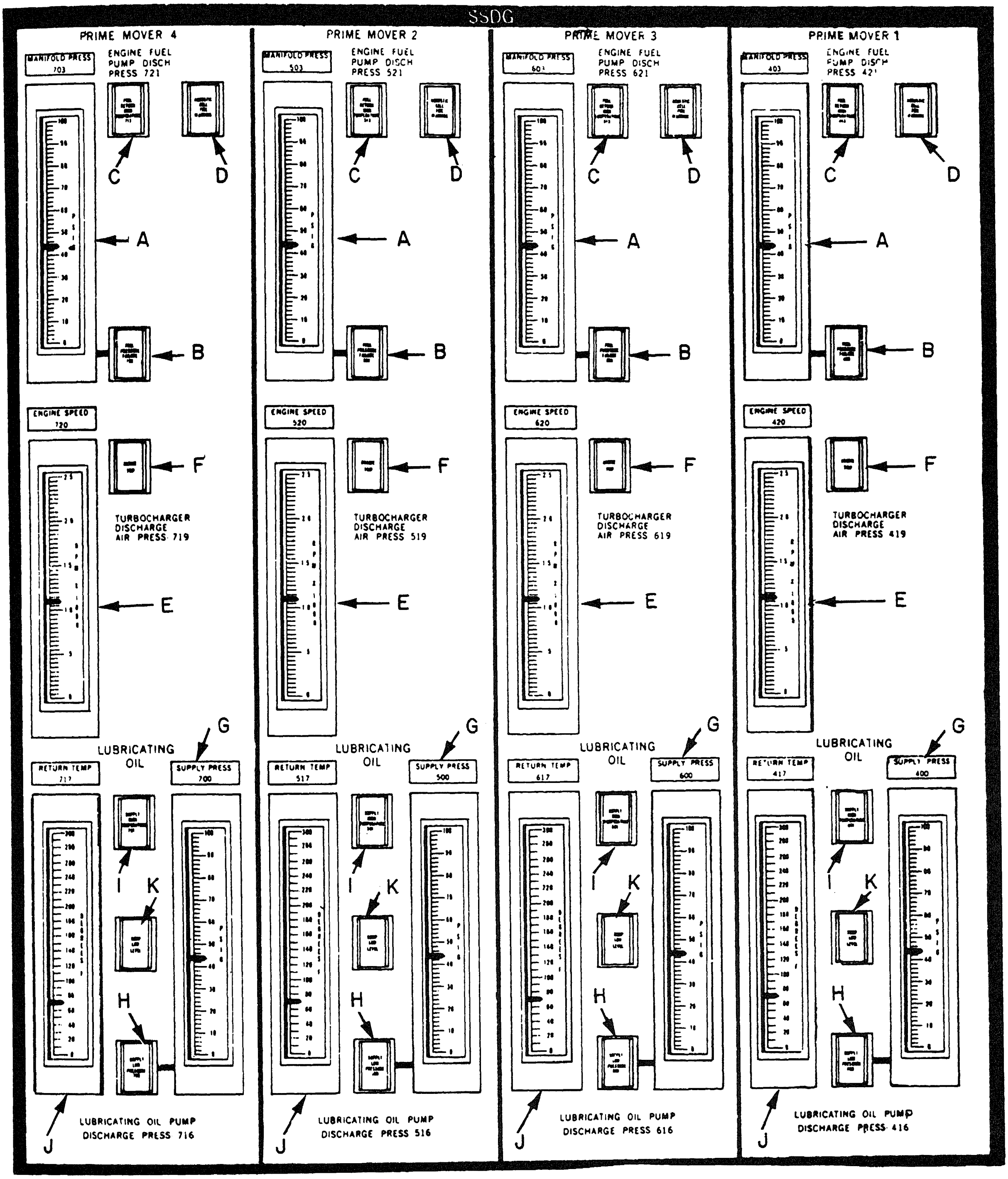

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Figure 10-28.—SSDG panel (A-4).

oil pressure, Halon release, or by corrective action of the SCS.

Diesel Engine Lubricating System

Lubricating oil (L.O.) is distributed to all vital points in each generator set from the engine-mounted lube oil pump which takes suction from a sump tank to the L.O. cooler. This is done through separate systems to the engine and the generator and back to the sump tank.

Pressure transducers are used at the L.O. supply line. Service pump discharge pressures are available at the EPCC as demand displays. Supply pressure (SUPPLY PRESS) are continuous displays on edgewise meters (G) and are also available as demand displays. The SUPPLY LOW PRESSURE alarms (H) are derived by console logic circuitry from the analog signal from the transducers. Also, a signal is provided to the SCS to initiate corrective action when the plant is under automatic control. The L.O. SUPPLY LOW PRESSURE alarms are automatically inhibited to prevent nuisance alarming on starts and when the PRIME MOVER STOP pushbutton is depressed.

The RTDs are used in the L.O. supply and return lines. Supply line temperatures are available as demand displays; the SUPPLY HIGH TEMPERATURE alarms (I) are derived by EPCC logic from the analog signals from the RTDs. Temperature of the return lines to the L.O. sumps (RETURN TEMP) are continuous displays on edgewise meters (J). They are also available as demand displays.

The L.O. sump tank liquid levels are detected by level switches. Closure of the switch contacts actuates the SUMP LOW LEVEL alarms (K).

SSDG PANEL (A-7)

The A-7 panel (figure 10-29) is used to monitor the condition of the diesel engine. This panel has indicators and meters to check the engine's cooling water, both salt water and jacket water, and to monitor the exhaust temperature of the engines.

Seawater System

Each generator set is provided with a motor-driven seawater circulating pump. This pump takes its sea suction through a motor-operated seawater suction valve, circulates the seawater through the heat exchangers, and discharges overboard through a motor-operated overboard valve. The diesel engine starting circuits are electrically interlocked with the position of their respective suction and overboard valves. This is to prevent engine cranking unless both valves are open. A backup supply of seawater is provided to each generator set's seawater system from the ship's firemain through pressure regulating valves. This is done so seawater will flow from the firemain through the heat exchangers and overboard upon loss of pressure from the generator seawater circulating pump.

Each generator seawater circulating pump is connected through a CB across the line terminals of the respective generator output so the pump starts and comes up to speed with the generator. Each SW PUMP RUNNING indicator light (A) is energized through auxiliary contacts on the respective pump CB in series with contacts on the relay that provides the signal to the respective GENERATOR RUNNING AND UP TO VOLTAGE light (located on another section of the console).

You can operate each suction valve and overboard valve from the EPCC when the local/remote control transfer switch is set on REMOTE. Lighted pushbutton switches (B and C) on the console operate the open and close control circuits to the valve motors. The lights in the pushbuttons indicate the pushbutton switch. Valve position indicators (D and E) are also provided. They show valve position if the control transfer switch is in the LOCAL or REMOTE position. The valves may also be operated manually at the valve.

Pressure transducers are used to sense pressure in the seawater supplies downstream of the

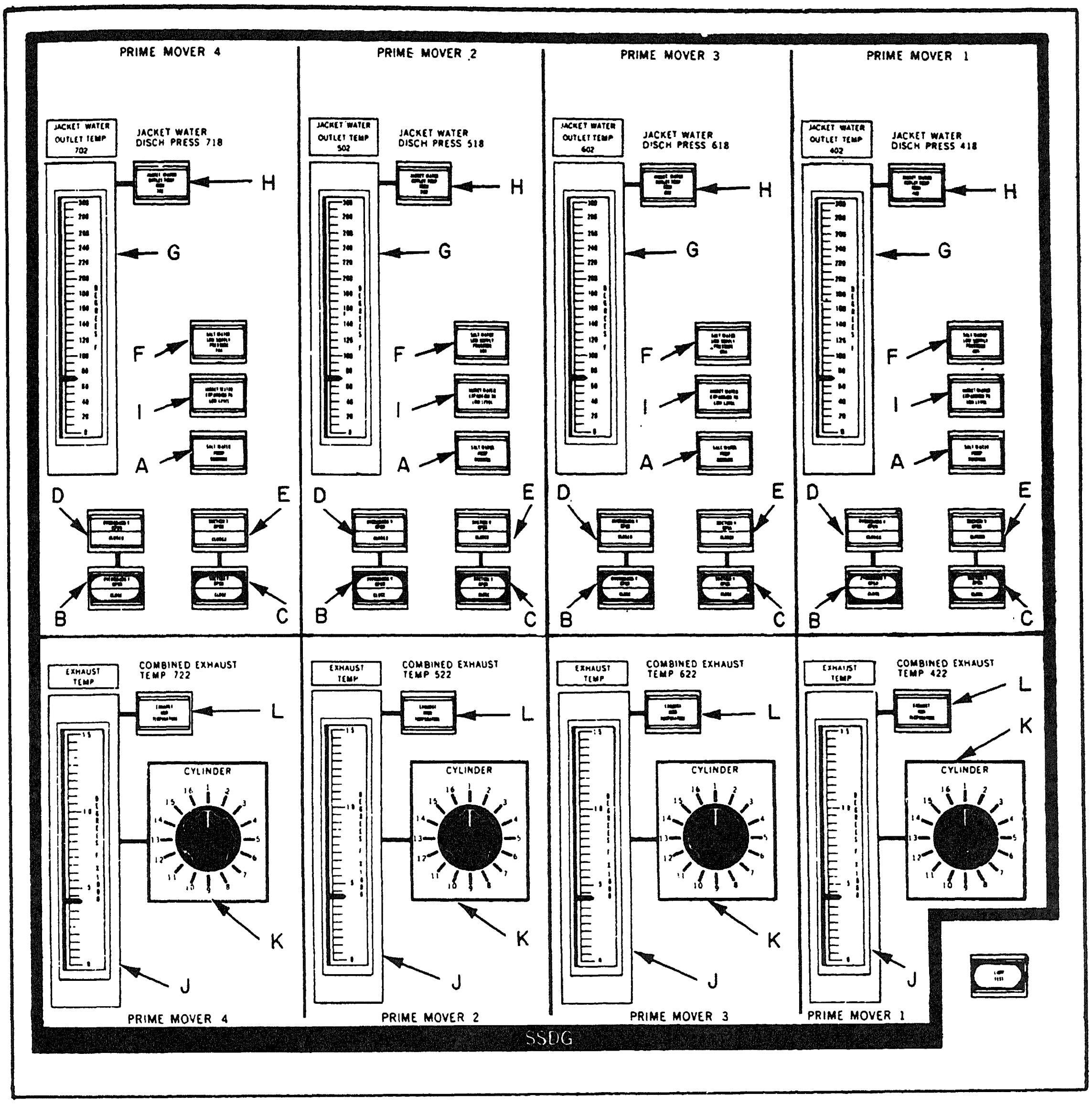

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Figure 10-29.—SSDG panel (A-7).

strainers. A signal proportional to supply line pressure is available at the EPCC as a demand display. A signal is derived from the analog signal from the transducers by console logic circuitry to actuate a SEAWATER LOW SUPPLY PRESSURE alarm (F) for each of the four seawater systems. The SEAWATER LOW SUPPLY PRESSURE alarms are automatically inhibited to prevent nuisance alarming when the PRIME MOVER STOP pushbuttons are pressed and during START before an engine run signal is received.

Jacket Cooling Water System

Cooling water is circulated in each diesel generator's jacket cooling water system by an engine-driven pump. Jacket water cooling is provided by a seawater-to-jacket water heat

exchanger and a jacket water-to-waste heat system heat exchanger. The jacket cooling water system also provides cooling for the diesel and generator lubricating oil system. The system also has an expansion tank to make up any water losses because of small leaks or evaporation.

The RTDs are installed in the jacket cooling water loops. Temperature of the cooling water loops are continuous display edgewise meters (G) and are also available as demand displays. The JACKET WATER OUTLET TEMP HIGH alarms (H) are derived by EPCC logic from the analog signals from the RTDs. "Heat soak" may cause the JACKET WATER OUTLET TEMP HIGH alarms to activate for a period of time after a diesel engine is stopped.

When water in the jacket cooling water expansion tank falls to a predetermined level, a contact closure completes the circuit to the JACKET WATER EXPANSION TK LOW LEVEL alarm indicator (I).

When there is no water flow in the jacket cooling water loop, a contact closure completes the circuit to an EPCC alarm indicator. This signal is also applied to the SCS which shuts down the generator when the SCS is in AUTO. The NO JACKET WATER FLOW alarms located on the supervisory control status panel are automatically inhibited to prevent nuisance alarming when the respective PRIME MOVER STOP pushbutton is pressed and before receiving an engine run signal on start-up.

Exhaust Temperature

Diesel engine exhaust temperature is measured by thermocouples mounted in each cylinder exhaust and at the outlet of the exhaust manifold. At the EPCC the signals are used to drive an EXHAUST TEMP edgewise meter (J). A selector switch (K) provides for the selection of each of the 16 cylinders. The combined exhaust (manifold) temperature is available as a demand display. When any cylinder temperature reaches a predetermined level, console logic circuitry activates an EXHAUST HIGH TEMPERATURE alarm (L).

SUPERVISORY CONTROL STATUS/ PARAMETERS/SYNCHRONIZATION/PARALLELING PANEL

This panel provides the alarm indicators for the SCS, synchroscope, and lamps to monitor synchronization, and a section to monitor and control the four automatic paralleling devices. It also has a list of parameters and addresses used by the three demand display readouts with address and limit switches.

Supervisory Control Status

The supervisory control status section (figure 10-30) provides the alarming for the SCS. Alarm indicators show the malfunctions that cause the SCS to take corrective action for each of the four generator sets. These six malfunctions are as follows.

1. FAULTY GOVERNOR (A)
2. BUS VOLTAGE LOW (B)
3. NO JACKET WATER FLOW (C)
4. GENERATOR VOLTAGE TOO HIGH (D)
5. GENERATOR EXCITATION TOO HIGH (E)
6. GENERATOR CB TRIPPED AUTOMATICALLY (F)

Also, alarm indicators are provided for overall plant malfunction between two or more operating generators. A STANDBY GENERATOR NOT AVAILABLE alarm indicator (G) is provided to alert the operator during a malfunction if the SCS cannot locate a nonoperating generator that has been set for automatic start. The four overall plant malfunction indicators are as follows.

1. REAL LOAD UNBALANCE (I)

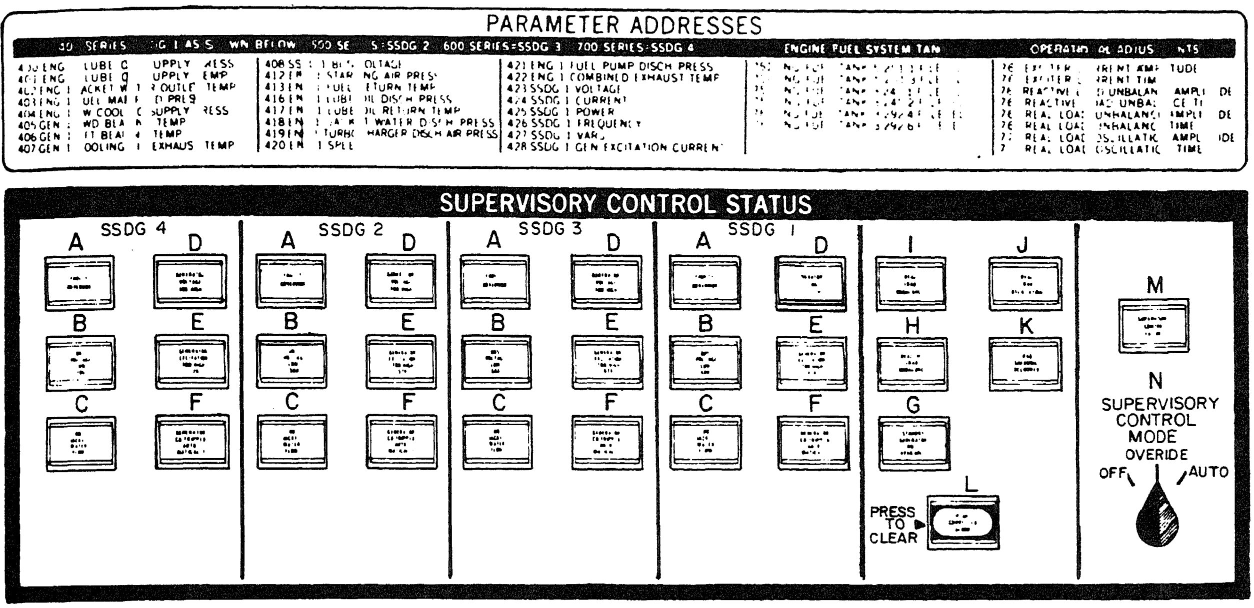

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Figure 10-30.—Supervisory control status panel.

2. REAL LOAD OSCILLATION (J)

3. REACTIVE LOAD UNBALANCE (H)

4. LOAD SHEDDING OCCURRED (K)

A PLANT CORRECTED alarm (L) is provided. It is an illuminated pushbutton used to notify the operator that the SCS has taken action to correct the plant following a malfunction. The malfunction alarm indicators remain illuminated until the PLANT CORRECTED alarm is pressed. This applies only to alarms that are activated by the processor. It provides the operator with an indication of the plant malfunction that caused the SCS corrective action. This would otherwise be canceled when the plant returns to a satisfactory operating condition. Alarm indicators activated by sensors external to the EPCC will not be extinguished by the PLANT CORRECTED alarm illuminated pushbutton.

The supervisory control failure indicator (M) illuminates to inform the operator of problems in the SCS. These problems may be either in the hardware or the program.

Operation of the SCS is controlled by the SUPERVISORY CONTROL MODE switch (N). This three-position switch determines the mode of the processor. The normal operating position is AUTO. It allows for full SCS control. In the OVERRIDE position, the SCS allows the operator to perform normal console operations such as paralleling without defeating normal SCS supervision. With the switch in OFF, the SCS processor has no monitoring capability and takes no corrective action.

The demands panel is identical to the demands panel on the PCC. The DDIs may be used to display any plant parameter with a DDI address.

Paralleling and Synchronization

By using an APD, you can parallel generators from the EPCC in one of three modes: auto, permissive, or bypass. Also, you can test the paralleling circuits by using a built-in test circuit. These modes are selected using the

four-position MODE switch (A) shown on figure 10-31.

In the automatic mode the APD automatically adjusts the speed of an oncoming generator to synchronize it with an energized portion of the electric system. It then provides a signal to close a designated CB when (1) the difference in frequency between the two points is less than 0.2 Hz, (2) the phase angle is less than 30 degrees, and (3) the voltage difference is less than 5 percent.

One of the two inputs to APD can be transferred to sense one of three inputs by a generator transfer selector switch (B). There is one for each APD, designated GENERATOR 1, GENERATOR 2, GENERATOR 3, and GENERATOR 4. The transfer switch positions correspond to the points in the electrical system that are to be paralleled. In the APD a non-transferable input is taken from the respective generator. This is because the APD automatically adjusts the speed of the generator prime mover to bring it into synchronism when the APD is in the automatic mode of operation. The APD will not permit CB closure unless it receives two input signals.

The four illuminated INITIATE pushbuttons (C) will actuate the respective APD. The INITIATE pushbutton is used only with the SCS

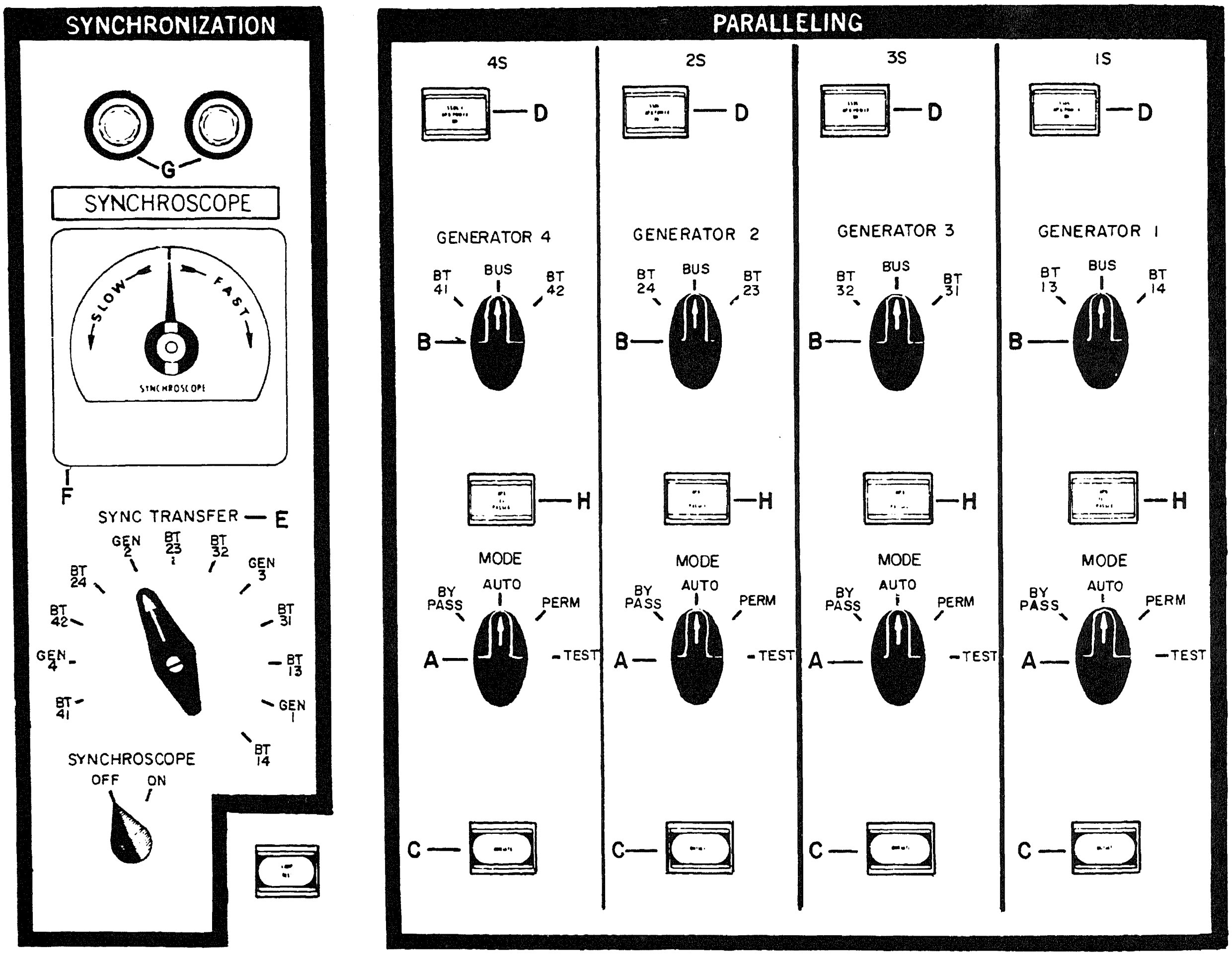

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Figure 10-31.—Paralleling and synchronization panel.

override to parallel in either the AUTO or
RM mode.

The SSDG APD POWER ON indicator lights
) show that the APD has initiated an AUTO
RALLEL. The APD POWER ON lights
inguish when the selected CB closes.

To cancel a lighted APD POWER ON in-
ator light that was initiated in error, turn the
pective generator transfer selector switch to
other position that will de-energize the initiate
cuit.

CAUTION

The INITIATE pushbuttons should be depressed only in the TEST mode to test the APD circuitry before shifting to the AUTO or PERM mode.

In the permissive mode the APD acts as a
ety interlock. It prevents closing of the
signated CB unless the previously mentioned
nditions are met. When operating in this mode,
APD does not control the governor of the
nerator's prime mover to automatically adjust
eed. In the permissive mode, the operator must
just the speed of the oncoming generator by the
VERNOR SPEED control switch. The
erator must observe conventional manual
ralleling procedures.

The BYPASS position is used only when the
D is inoperative, or when APD permissives
nnot be met. This position bypasses the APD's
closing permissive interlock contacts. Manual
ralleling by the operator is required. The
DE selector switch is spring returned from
PASS to AUTO. It must be held in the
PASS position by the operator while the CB
ntrol switch is thrown to the CLOSE position.
is is done when the two points in the electric
nt to be paralleled are in synchronism. Also,
s necessary to use the APD BYPASS position
close a CB to a dead bus and the last breaker
a ring bus. Under this mode of operation, the
chronizing lights glowing bright and steady will
ify the dead bus.

When paralleling in either the permissive or
pass mode, you must use the synchroscope and
chronizing lights to verify when generator
ase relationships are within required limits.

A SYNC TRANSFER switch (E) selects the two points in the electrical power system between which synchronizing is desired. Switch position designations using prefix letters BT correspond to the BTB control switch designations on the mimic bus on the MIMIC panel. This will provide an indication of synchronization between points on either side of the BTBs. For example, switch position BT 4-1 connects the SYNCHROSCOPE (F) and synchronizing lights (G) between the bus of switchboard 4S and the bus tie 1S-4P-4S. Switch positions designated GEN 1, GEN 2, GEN 3, and GEN 4 correspond to the respective GBs. They connect the SYNCHROSCOPE and synchronizing lights between the line side of the GB and the switchboard bus.

Accordingly, transfer switch position designations preceded by BT provide an input from the bus ties. For example, the position on GENERATOR 4 transfer switch marked BT 4-1 provides an input from bus tie 1S-4P-4S to the APD on SS switchboard 4S. In this position and with the corresponding MODE selector switch in the AUTO position, the speed of SSDG4 is adjusted to bring it into synchronism with bus tie 1S-4P-4S. This also provides a signal to close the bus tie 4-1 CB. In this manner, the transfer switch position marked BUS selects an input from the generator's own switchboard bus. When in this position, the speed of the generator is adjusted to bring it into synchronization with the energized bus of its own switchboard. This provides a signal to illuminate the APD test passed light and to close the GB.

The TEST position permits all the features of the APD automatic mode. However, in this mode the APD does not provide the signal for CB closing. Instead, it provides a signal to illuminate the respective APD TEST PASSED indicator light (H). This mode should be used with the SYNCHROSCOPE and proper VOLTAGE and FREQUENCY meters to check the performance of the APD. The APD TEST PASSED indicator light illuminates at the same point of synchronization at which the signal for CB closing would have occurred. This point should be when the frequency difference between the two points is less than 0.2 Hz and when the needle of the SYNCHROSCOPE is close to and approaching the midpoint mark.

CAUTION

Each APD adjusts the speed of only its own generator. All paralleling operations in the APD AUTO mode are accomplished by bringing single-running machines into synchronization with machines operating in parallel. Never attempt to drive machines operating in parallel into synchronism with single-running machines.

Chapter 12 of this RTM has a discussion of paralleling procedures and theory. Refer to that material to gain a better understanding of the use of paralleling controls.

SSDG OUTPUT AND DISTRIBUTION PANEL (A-5)

Located in the center of the EPCC is the SSDG output and distribution panel (figure 10-32). This panel contains four identical sections. There is one section for each SSDG. The controls and indicators on this panel are used to monitor and control the output of the generator.

The meters on the panel are used to monitor FREQUENCY (A), CURRENT (B), VOLTAGE (C), and POWER (D). These meters are directly wired to the SS switchboard they monitor. Therefore, they operate whether or not the EPCC is powered up.

Generator Governor

Each generator diesel engine prime mover is provided with an electrohydraulic load sharing governor. It senses load differences between paralleled generators and automatically adjusts the load between the generators. The governor systems can automatically maintain constant speed of the generator sets regardless of load changes.

The GOVERNOR MODE selector switch (E) is provided with two positions, ISOCHRONOUS and DROOP. In the ISOCHRONOUS position, the generators maintain constant speed through load changes. The governors of paralleled generators adjust the load shared by each. This is the normal operating mode. In the DROOP position, the speed of the generator set decreases with load increase. All generators operating in parallel should have their GOVERNOR MODE selector switches set in the same position. This is whether the generator is controlled locally at its switchboard or remotely at the EPCC. DROOP and ISOCHRONOUS indicator lights show the status of the governor mode if its respective generator is under local control at the switchboard or remote control at the EPCC.

The GOVERNOR SPEED switches (F) operate motor-driven potentiometers in the governor controller of their respective switchboards. These switches change the frequency output of each generator.

Generator Voltage Regulators

Each generator is provided with a static exciter/voltage regulator with manual and automatic modes and differential and droop modes. VOLTAGE REGULATOR AUTO and MANUAL indicator lights (G) are provided on the EPCC for each generator. Operation from the EPCC must always be in the automatic mode. This is selected by a selector switch located on SS switchboards 1S, 2S, and 3S for SSDG1, SSDG2, and SSDG3, respectively. Operation in the manual mode for these generators is only possible at the switchboards and not from the EPCC.

However, the EPCC is the local operating position for SSDG4. For this reason a VOLTAGE REGULATOR AUTO/DE-ENERGIZE/MANUAL selector switch (H) and a VOLTAGE REGULATOR MANUAL ADJUST rheostat is provided on the EPCC for SSDG4. Operation in the manual mode requires constant surveillance of meters and manipulation of the VOLTAGE REGULATOR MANUAL ADJUST rheostat by the operator. It should be used only when the voltage regulator is inoperative. (NOTE: This rheostat is located next to the system's output monitor panel.)

The VOLTAGE REGULATOR MODE selector switches (I) select either the DIFFERENTIAL or DROOP mode of operation. The normal operating mode for generators operating in parallel is differential. When in this mode, the reactive load of all paralleled generators is adjusted in proportion to the difference in reactive current between them. The VOLTAGE REGULATOR MODE selector switches of all paralleled generators must

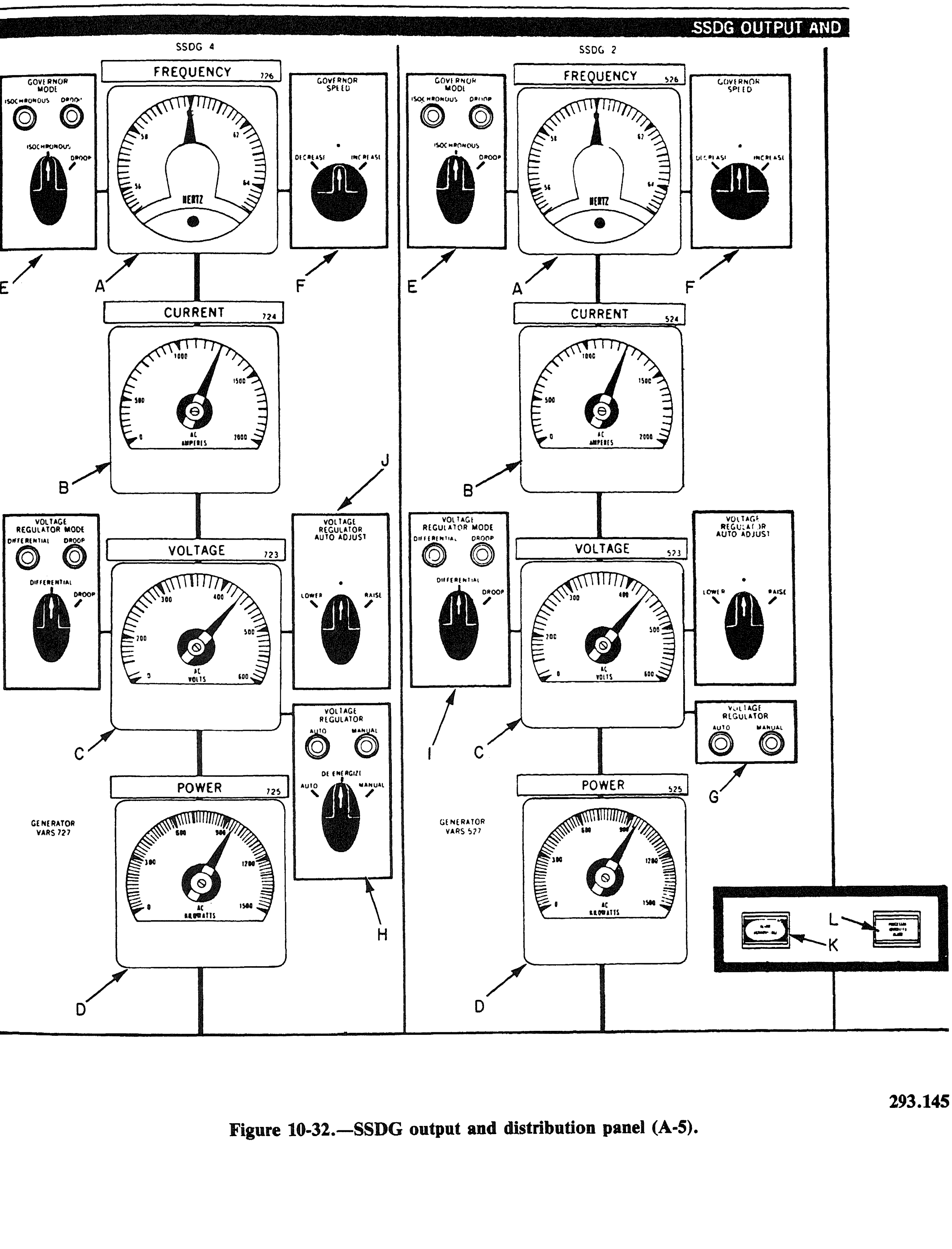

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Figure 10-32.—SSDG output and distribution panel (A-5).

be in the DIFFERENTIAL position for this mode to be operational. In the droop mode, the reactive load of each generator is in proportion to the reactive current rating of that generator. This results in a slight voltage droop in the system when reactive loads are added.

DIFFERENTIAL and DROOP indicator lights show the status of the voltage regulator mode if its respective generator is under local control at the switchboard or remote control at the EPCC.

The VOLTAGE REGULATOR AUTO ADJUST switches (J) operate motor-driven

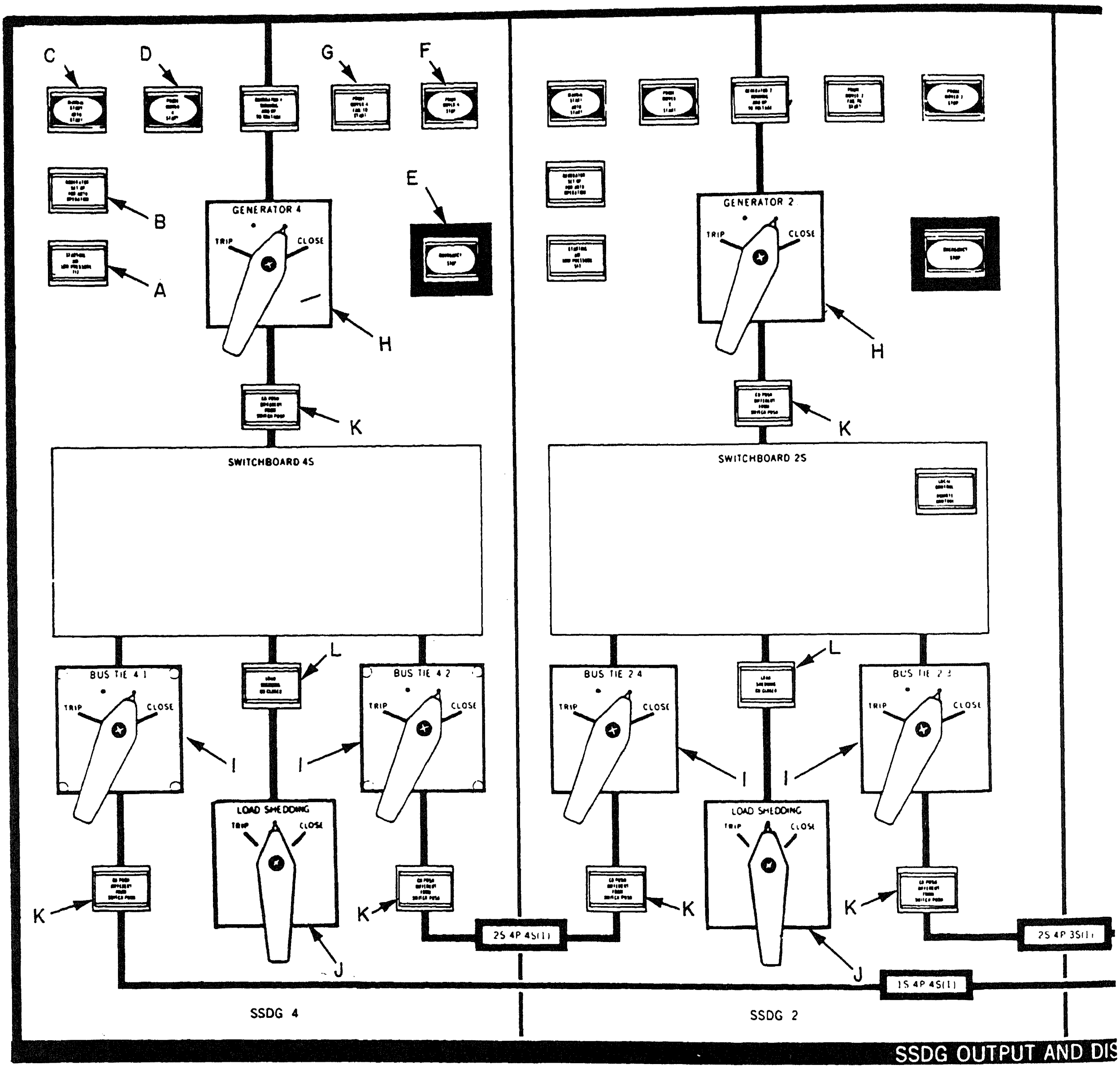

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Figure 10-33.—SSDG output and distribution panel (A-8).

potentiometers located in the SS switchboards. Each of these switches manually changes its respective generator's preset operating voltage level when the voltage regulator is in the automatic mode.

Alarm Acknowledge

The ALARM ACKNOWLEDGE pushbutton (K) is located on the SSDG output and distribution panel. When an out-of-tolerance condition in a system being monitored is sensed at the EPCC, the associated alarm is actuated. It is accompanied by a flashing alarm annunciator whose legend identifies the fault condition. The operator acknowledges the alarm by pressing the ALARM ACKNOWLEDGE pushbutton. The audible portion of the alarm is silenced and the visual light stops flashing but remains illuminated. The light remains illuminated until the cause of the fault alarm has been cleared. This pushbutton is used to acknowledge any alarm on the EPCC.

Processor Generated Alarm

The processor is a special purpose computer which is located in the EPCC. When an out-of-tolerance condition occurs on equipment being monitored, an alarm is generated in the EPCC by the fault alarm circuit. The status of the parameter is also checked by the processor. The processor compares the signal with the alarm set value to determine if an out-of-tolerance condition exists. If the condition does exist, the processor checks the equipment fault alarm circuitry to determine if the fault alarm has been actuated. If the fault alarm has not been actuated but an alarm condition is detected by the processor, the PROCESSOR GENERATED ALARM indicator (L) flashes and an audible alarm sounds.

SSDG OUTPUT AND DISTRIBUTION PANEL (A-8)

The SSDG output and distribution panel (A-8) (figure 10-33) contains a mimic bus depicting the physical arrangement of the electric plant and bus ties. The mimic bus also provides for manual start and stop control of the generators, generator bus ties, and load shedding CB manual control and position indication.

Engine Starting and Stopping

Air pressure for starting each diesel engine is taken from the ship's HP air compressors. A pressure transducer in the air pressure supply line provides a signal proportional to air supply pressure. It is available at the EPCC as a demand display. When pressure falls to 100 psig or less, console logic circuitry energizes the STARTING AIR LOW PRESSURE alarm (A).

Four GENERATOR SET UP FOR AUTO OPERATION indicator lights (B) are provided, one for each generator set. These indicate that all the devices necessary for the respective diesel engine to remotely start (either in automatic or manual mode) and automatically parallel with the main bus are properly lined up. The devices included in the series circuit for each of these lights and the proper position of these devices for engine automatic start and operation are as follows.

Device	Position	Control Location
Starting air shutoff valves	OPEN	At valve (manual)
Auxiliary fuel service shutoff valve(s)	OPEN	At valve (manual)
Engine cranking lock-out switch	ON	Diesel engine control panel
A normally closed contact of relay K5 on engine control panel	CLOSED	Engine trouble reset switch on engine control panel
Voltage regulator selector switch	AUTO	SS switchboards 1S, 2S, and 3S for SSDG1, SSDG2, and SSDG3. EPCC for SSDG4.
Local/Remote switch	REMOTE	SS switchboards 1S, 2S, and 3S for SSDG1, SSDG2, and SSDG3. AMR No. 3 for SSDG4 (LOCOP).
Saltwater suction valve	OPEN	EPCC (See note)
Saltwater overboard valve	OPEN	EPCC (See note)

Device	Position	Control Location
Auxiliary fuel service suction valve(s)	OPEN	EPCC (See note)
APD generator (transfer) switch	BUS	EPCC
APD MODE selector switch	AUTO	EPCC

NOTE: Control of the valve from the EPCC is operable only if the Local/Remote switch at the valve controller is in REMOTE position.

When the GENERATOR SET UP FOR AUTOMATIC OPERATION indicator is illuminated and the MANUAL START/AUTO START illuminated pushbutton (C) is in the AUTO START position, a signal is sent to the SCS that the generator is available as a standby generator.

A PRIME MOVER START pushbutton (D) is provided for each generator set. The pushbutton is operative only when its adjacent MANUAL START/AUTO START illuminated pushbutton (C) is in the MANUAL START position.

The guarded EMERGENCY STOP pushbutton (E) operates to shut off fuel and combustion air to the respective generator's diesel engine. It should be used only in emergency situations. The shutdown devices must be reset at the engine when the EMERGENCY STOP pushbutton is used. Normal manual shutdown is the PRIME MOVER STOP pushbuttons (F). They shut off fuel to the engines.

The PRIME MOVER FAIL TO START alarm (G) occurs if its respective generator fails to start after a cranking period of 15 seconds. This alarm is activated by contacts in the respective diesel engine control panel.

Circuit Breaker Control

Control switches are provided for each generator (H), bus tie (I), and load shedding (J) CBs. The control switches for BTBs and GBs are four-position switches. They are spring returned from the outermost position on each side to the adjacent innermost position.

The two outermost positions of the switch, labeled TRIP and CLOSE, send the signal to actually operate the breaker when held in either position. The two inner positions of the switch set up a circuit through auxiliary contacts. The CB POSN DIFFERENT FROM SWITCH POSN indicator (K) will illuminate if a difference in breaker and switch positions exists. To operate a GB or BTB, turn the switch to the desired extreme outermost position TRIP or CLOSE. Then release the switch handle which returns to the adjacent innermost position. To acknowledge and cancel a CB POSN DIFFERENT FROM SWITCH POSN indicator light, the switch must be turned to the other innermost position. This will cause the switch to agree with the actual position of the CB and set up the indicator light for the next automatic operation of the CB. The bus tie and generator control switches can be used as a status board for overall plant monitoring when the electric plant is under local control at the switchboards.

The four LOAD SHEDDING CB control switches operate in the same manner as CB control switches on the SS switchboards. These switches are spring returned from the outer TRIP and CLOSE operating positions to the center position. A blue LOAD SHEDDING CB CLOSED indicator light (L) is provided for each of the four load shedding CBs.

The load shedding system is a local automatic system contained in the SS switchboards. The system operates when the plant is in either local control at the switchboard or remote control at the EPCC. When a load sensing relay senses an overload on its generator, the relay sends a signal to trip a load shedding CB on each of the four switchboards simultaneously. The load shedding CBs disconnect a bus section in their respective switchboards. Thus, less vital services are de-energized and the load on the electrical system is reduced to the capacity of a single generator set. When electric plant capacity has been restored after load shedding, the four load shedding CBs must be individually re-closed manually by the LOAD SHEDDING CB control switches.

CONSOLE POWER STATUS/VITAL POWER FEEDER CIRCUIT BREAKER STATUS PANEL

This panel provides a display of vital power feeder CB positions. It also displays the

availability of console internal power and EPCC temperature conditions. Figure 10-34 shows the layout of this panel.

Console Power Status

The EPCC is energized by two separate sources of 115-volt, single-phase, 60-Hz a.c. power. The supply for EPCC operation comes from the UPS located in the engine room. The UPS feeds the EPCC through a 25-ampere automatic CB, circuit K-ECC1, in the power panel 2-278-3 located in the engine room. You can find more information on the UPS system in chapter 11.

Under the section heading marked UNINTERRUPTIBLE POWER, the green NORMAL indicator light (A) shows that the 115-volt a.c. SS supply is being rectified by the rectifier/battery charger and changed to a.c. by the inverter. The amber ALTERNATE indicator light (B) shows that the inverter has failed and is being bypassed. The (red) BATTERY alarm (C) shows that SS power to the UPS has failed and the UPS is operating on the storage batteries.

The EPCC contains redundant power supply units for converting the 115-volt, single-phase,

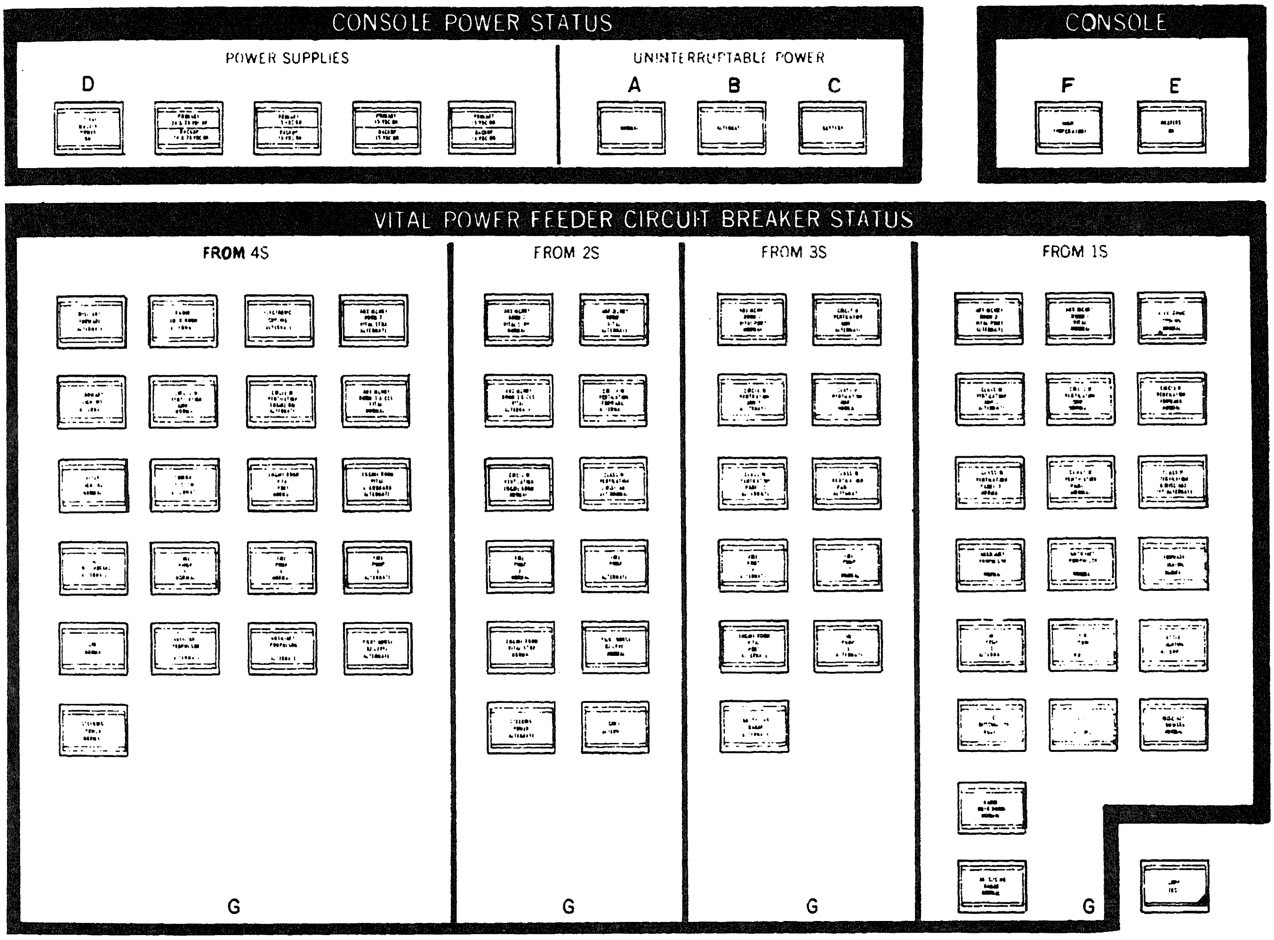

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Figure 10-34.—Console power status/vital power feeder circuit breaker status panel.

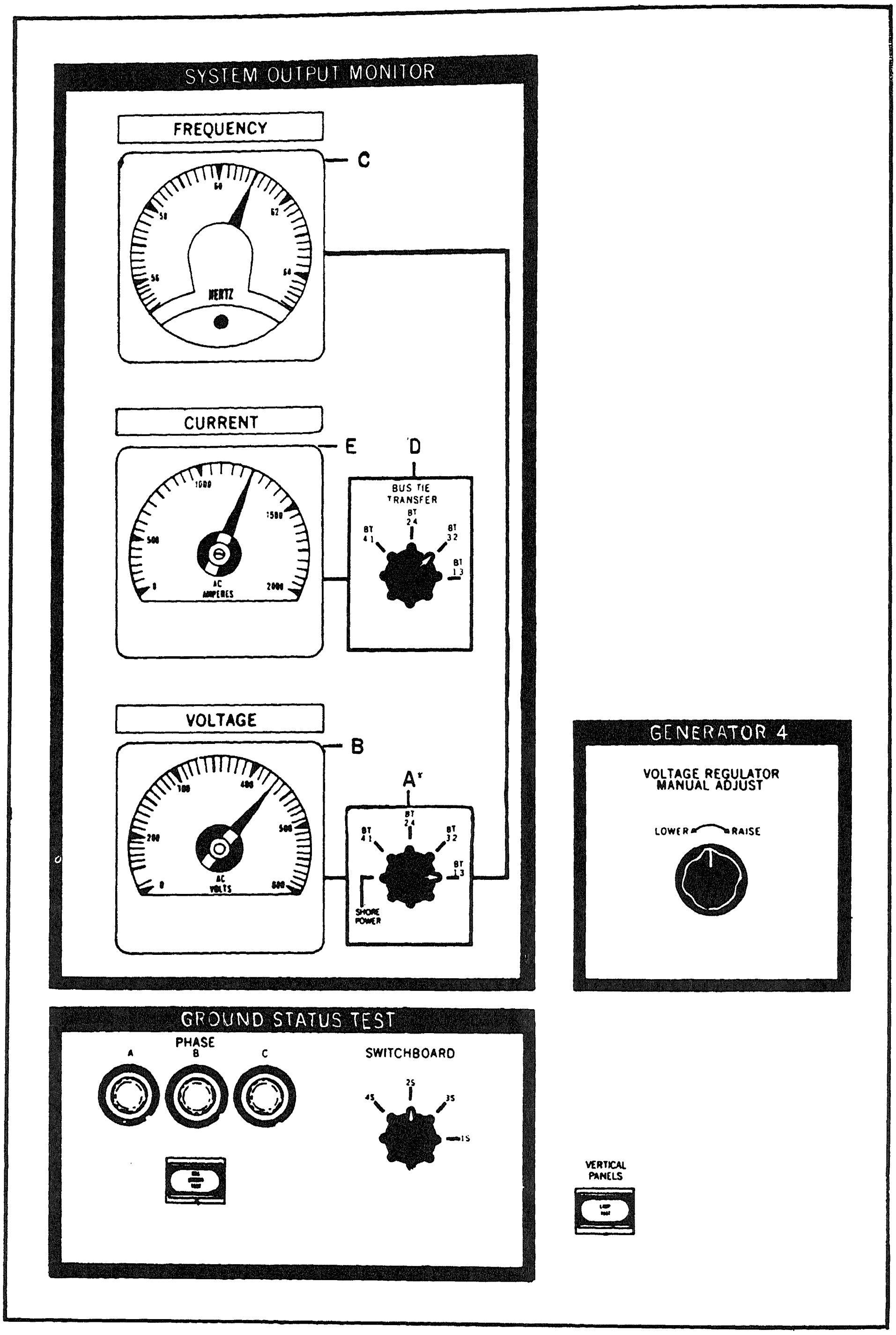

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Figure 10-35.—System output monitor/ground status/SSDG No. 4 panel.

60-Hz a.c. supply from the UPS to the voltages required by the console. When the split indicator lights on the section titled POWER SUPPLIES are illuminated, the respective power supplies are switched on and are functioning. The power supplies are mounted at the rear of the EPCC; each one is energized by setting the A.C. INPUT switch to ON. The 115 VAC MASTER POWER ON indicator light (D) on this section lights to indicate the availability of 115-volt, single-phase, 60-Hz a.c. at the console's input terminals from the UPS.

Console Heaters

The status of the power supply for the console heaters is not separately shown on the EPCC. The heaters are automatically switched on by a relay in the console when the 115-volt a.c. power supply to the console from the UPS is switched off in power panel 2-283-2. The HEATERS ON indicator light (E) on the console section of the panel provides indication that the power is available for the heaters and that the relay contacts have closed. The HIGH TEMPERATURE alarm (F) shows console temperature has exceeded a preset value.

Vital Power Feeder Circuit Breaker Status

Tripping and closing of individual feeder CBs are not controlled at the EPCC. The illuminated indicator lights (G) on this section of the panel show that the particular CB is open. These indicator lights are limited to only those CBs feeding vital services.

SYSTEM OUTPUT MONITOR/ GROUND STATUS TEST/ GENERATOR NO. 4 PANEL

This panel (figure 10-35) monitors system frequency and voltage of the bus ties and shore power and the current in the bus ties. It also provides means for checking the ground condition on the main bus and for manually controlling the voltage of generator No. 4. A selector switch (A) is provided for the SYSTEM OUTPUT MONITOR VOLTAGE (B) and FREQUENCY (C) meters to select readings from the four bus ties and shore power. A selector switch (D) is provided for the CURRENT meter (E) to display the current in each of the four bus ties and shore power.

SHORE POWER/GENERATORS PANEL

This panel (figure 10-36) monitors the current of the connected shore power and provides position indication and tripping control of the shore power CBs. It also monitors the mechanical parameters of the generators, such as bearing, stator, and cooling air temperatures. Related alarms are energized when emergency conditions exist. It also has control and indication for the generator space heaters.

Shore Power

The CURRENT meter (A) on the SHORE POWER section displays the current in the common shore power bus in SS switchboard 3S. Paralleling when coming on to shore power must be done at SS switchboard 3S regardless of SSDGs on the line. However, if SSDG No. 3 is inoperative, paralleling can be done using any SSDG combination, but always from the No. 3 switchboard. The seven blue-colored CIRCUIT BREAKER CLOSED indicator lights (B) show the closed status of the seven shore connection CBs located on SS switchboard 3S.

Generator

Generator bearing temperatures are measured by RTDs in the two generator bearings. Both signals provide a demand display at the EPCC. This provides a capability to read bearing temperatures when needed, especially when a high temperature condition exists in either bearing. Console logic circuitry activates the FORWARD BEARING HIGH TEMP alarm (C) and the AFT BEARING HIGH TEMP alarm (D), as applicable. "Heat soak" may cause these alarms to activate for a period of time after the generator set is stopped.

Generator cooling air exhaust temperature is measured by an RTD. The data is available at the EPCC as a demand display. When a high temperature condition exists, console logic

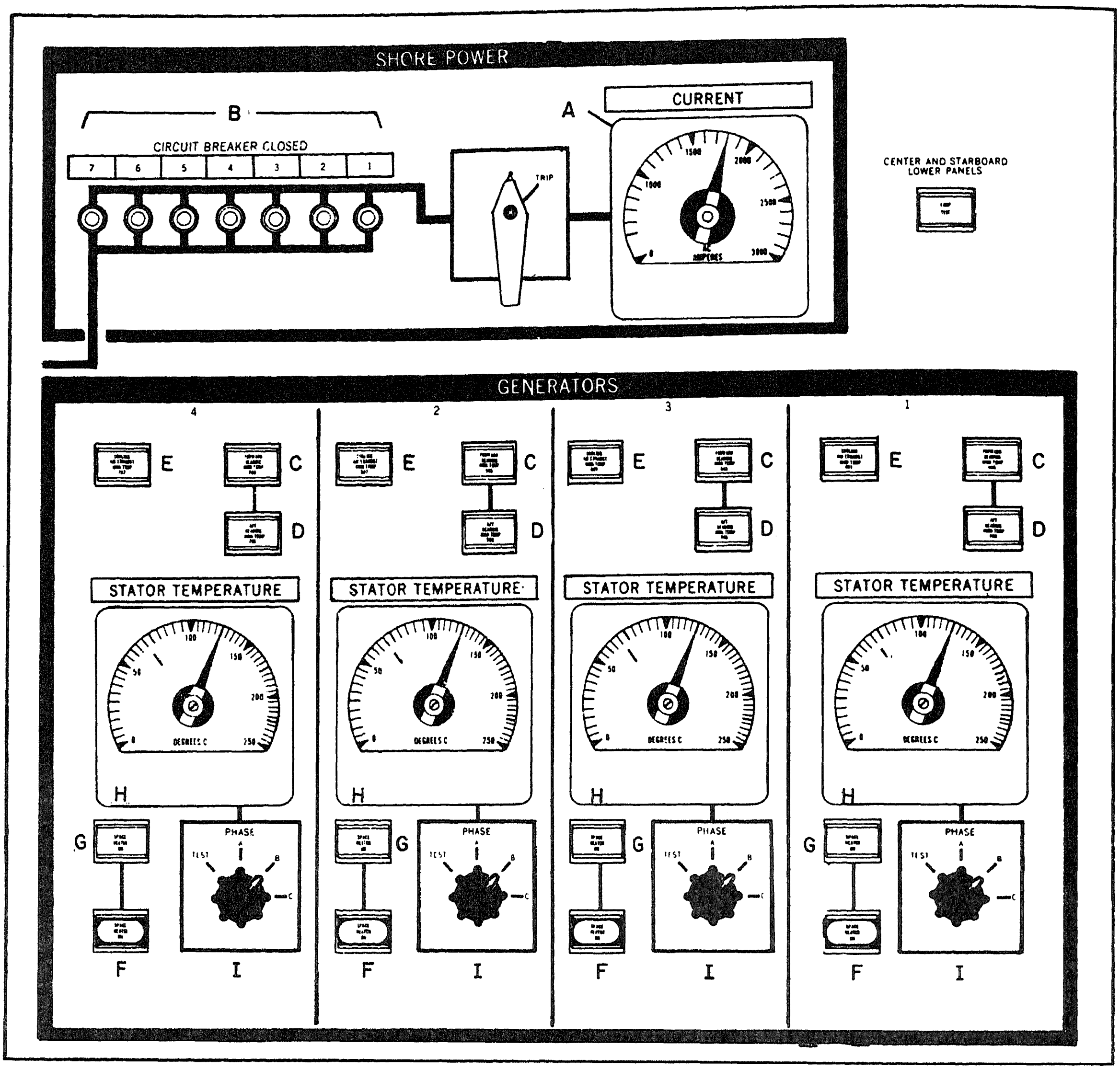

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Figure 10-36.—Shore power/generators panel.

circuitry activates the COOLING AIR (EXHAUST) HIGH TEMP alarm (E).

The generator space heaters can be controlled at the EPCC. The four SPACE HEATER ON lighted pushbuttons (F) control the space heaters in their respective generators by operating relays in the SS switchboards. The heater local ON/OFF switch controls the space heater by operating the same relay. Either the SPACE HEATER ON pushbutton on the EPCC or the heater local ON/OFF switch can turn the heater on. The indicator light in the pushbutton indicates the ON status of the console remote control circuit. The relays controlling the space heaters are automatically de-energized for running generators by auxiliary contacts on the respective GB. They are re-energized when the generator set is shut down provided the SPACE HEATER ON pushbutton or the local ON/OFF switches are in the ON position. The separate SPACE HEATER ON

indicator light (G) on the EPCC shows that the space heater has been turned on using either the EPCC SPACE HEATER ON pushbutton or the local ON/OFF switch.

Generator stator temperature is measured by three RTDs, one in each phase. The signals are used to drive a stator temperature meter (H) in the EPCC. A selector switch (I) provides for the selection of Phase A, B, or C.

DAMAGE CONTROL CONSOLE

The DCC (figure 10-37) on the FFG-7 class ships has many of the same features as the DCC on the *Spruance* class. From this console an operator may monitor and/or control many of the damage control systems installed on the *Perry* class frigates. These systems include the following.

- AFFF sprinkling system valves
- Halon flooding system
- High water alarm
- Sprinkling systems
- High temperature alarms
- Supply fans
- Fire zone doors
- Exhaust fans
- Recirculating fans
- Ducting closures
- Firemain pumps and valves

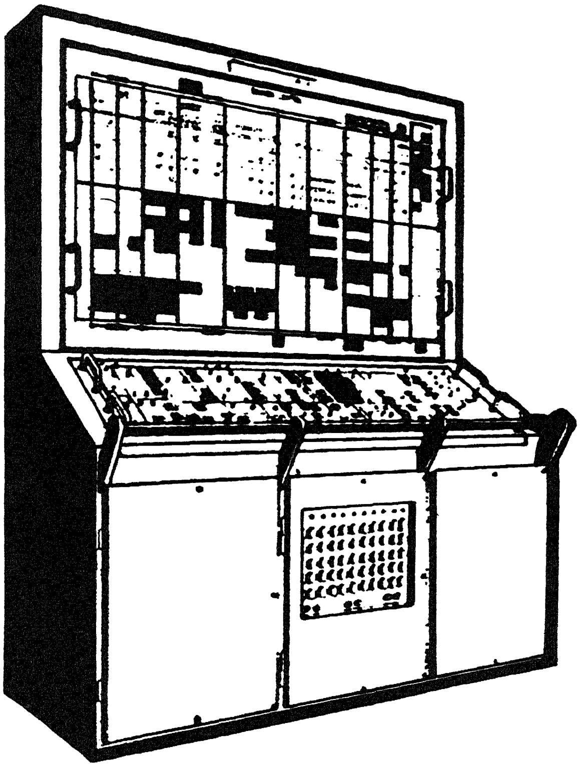

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Figure 10-37.—Damage control console.

DCC UPPER PANEL

The upper panel of the DCC (figure 10-38, two foldouts at the end of this chapter) is used to monitor most of the systems of the DCC. This panel is divided into three major sections with each section further divided into subsections. The three major sections are labeled as follows.

1. Misc. Fire Fighting
2. Alarm and Detection
3. Ventilation

Misc. Fire Fighting

This section is the uppermost section of the top panel. It is divided into two subsections. These are AFFF sprinkling system valves and Halon flooding system. The AFFF sprinkling system valves subsection shows the status of the four AFFF sprinkling valves. These valves are used to control the sprinkling of AFFF at the two vertical replenishment (VERTREP) stations, fore and aft, and the sprinkling systems in the two helo hangars. These valves are activated locally and their open/closed status is shown on the DCC.

The other subsection is the Halon flooding system. Halon is the extinguishing agent used to combat fires in high risk areas. It is used to protect both GTM modules, all four SSDG enclosures, the engine room, all three auxiliary machinery rooms, the RAST equipment room, the paint mixing room, and the flammable gas and liquid storerooms. The DCC has indicators to display when Halon has been released to one of these spaces.

Alarm and Detection

This section of the upper panel is below the misc. fire-fighting section and contains three subsections. These subsections are high water levels, sprinkling systems, and high temperature.

The high water level indicators are used to monitor water levels in spaces that have a high potential for flooding. There is a total of 11 of these alarms for spaces such as the engine room, auxiliary machinery rooms, and several other equipment rooms.

Four alarm indicators are in the sprinkling systems subsection. These are used to display the status of sprinkling systems other than the AFFF systems. These systems are located in three magazine spaces and the trash disposal room. These sprinklers use salt water from the firemain system.

The last major subsection in this section is the high temperature section. There are 81 indicators activated by temperature sensors located throughout the ship. They are used to alert the operator if fires are detected in any ship spaces.

Ventilation

The largest section of the top panel is the ventilation section. This section contains four subsections: three to monitor fan status and one to monitor duct closures. No control is available here, only monitoring capability.

The top subsection is used to monitor the supply fans. Twenty-four split-type indicators display either running or stopped status of the supply fans they monitor.

The exhaust fans section, located below the supply fan monitors, has 23 split-type indicators. These are used to monitor the on/off status of 23 exhaust ventilation systems.

The recirculation fans are monitored by the next section. The 28 recirculation systems have their status displayed in this portion of the panel.

Below the recirculation system monitoring section are 46 indicators used to monitor ducting closures. They display the open/closed status of a variety of watertight, blowout, and fire zone closures.

The only control feature on the top panel is located on the lower right side. It is labeled FIRE ZONE DOORS. When this pushbutton is depressed, the console sends out a signal to close the fire boundary smoketight doors. This is used to prevent the spread of smoke throughout the ship during fires.

DCC LOWER PANEL

The lower panel of the DCC (figure 10-39, a foldout at the end of this chapter) is used to monitor and control the ship's firemain system. This panel has a complete mimic of the major piping of the firemain. Some of the capabilities available from this panel include:

- firepump on/off control (five pumps),
- control of major isolation valves (20 valves),
- AFFF proportioner activation indication,
- minor isolation valve indication,
- firemain pressure indication (two meters), and
- firepump power status.

Operation of the firemain system is fairly easy. You can start or stop pumps by depressing either the pump run or pump stop pushbutton. These pushbuttons also serve as indicators of pump status. The motor-operated isolation valves each have one split-type indicator to display their status. A split-legend pushbutton is also provided to allow operation of the valves.

During general quarters, condition ZEBRA, the firemain is segregated into two loops. In this mode three motor-operated valves must be closed. This provides for an upper and a lower loop. The upper loop is served by firepumps 3 and 4.

The lower loop is fed by pumps 1, 2, and 5. Since the firemain pressure may be different between the loops, two pressure meters are provided; one is for the upper loop and one for the lower loop.

AUXILIARY CONTROL CONSOLE

The ACC (figure 10-40) is used to operate and monitor the status of a majority of the auxiliary systems in the engineering plant. The following systems may be operated or controlled from the ACC.

- Machinery space ventilation
- Fuel filling, transfer, and purification system
- Chilled water circulating system
- Waste heat water circulating system
- Compressed air plants
- Main engines starting air system

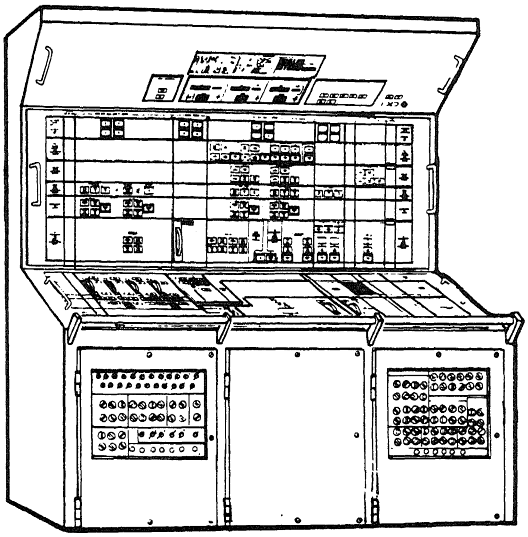

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Figure 10-40.—Auxiliary control console.

- Air-conditioning and ship's stores refrigeration plants
- Potable water system including fill valves
- Distilling plants
- Masker, prairie/fin stabilizer, and bleed air systems
- Sewage disposal system
- Saltwater service system
- Drainage system

In addition, the ACC has three digital displays. They, like the other displays, may be used to monitor any parameter having a DDI address.

ACC VERTICAL PANEL

The ACC vertical panel is shown on figure 10-41, a foldout at the end of this chapter. This panel contains the controls and indicators for seven of the systems on the ACC.

Machinery Space Ventilation Fans (Emergency Use)

Eight pairs of pushbutton switches are provided for emergency control of the machinery space supply and exhaust fans. Each pair has a FANS RUN and a FANS STOP pushbutton. Status of the fans is indicated by the lights in the respective pushbuttons.

The machinery space ventilation fans are located in the engine room and auxiliary machinery rooms No. 1, 2, and 3. There are supply and exhaust fans in each room. Under normal conditions, the fans are started from the local controllers and left in the LOCAL/REMOTE mode. This allows further controller operations from both the local controller and the remote panel. If an emergency exists, the switches at the ACC are used. The local controller switch must be in the LOCAL/REMOTE position for the pushbuttons on the ACC to be operational.

Fuel Filling, Transfer, and Purification System

This section has controls and indicators for the purifier, transfer pump, and stripping pump in the fuel filling, transfer, and purification system. The controls have EMERGENCY STOP pushbuttons for each of the components. Indicators are provided to monitor the status of the purifier speed, discharge, and vibration and the status of the transfer pump and the stripping pump. All the equipment monitored is located in auxiliary machinery room No. 2.

The fuel filling, transfer, and purification system is used to distribute fuel from the deck filling connections to the fuel storage and overflow tanks. It also discharges fuel from the storage and overflow tanks via the deck connections. It is used to transfer fuel between storage tank groups to adjust trim and list. One of its primary jobs is to transfer fuel to the service tanks via the fuel transfer heaters and centrifugal purifiers. The system is designed for local start-up and unattended operation.

Chilled Water Circulating System

This section has alarms and indicator lights used to monitor the chilled water circulating system. Indication is given of the chilled water circulating pump status. The alarms alert the operator to three occurrences. These are a high- or low-chilled water temperature condition, a circulating pump discharge pressure failure, or a low level in the chilled water expansion tank.

The chilled water circulating system distributes fresh cooling water throughout the ship for environmental control (air-conditioning), electronic equipment cooling, and bubbler drinking water cooling. The system can be divided into three independent loops. Each loop operates in conjunction with an air-conditioning plant. The circulating equipment for two loops is located in auxiliary machinery room No. 2. The third is located in the air-conditioning machinery room. The system is designed for local alignment, local start-up, and unattended operation. This system is normally configured in a closed loop with one air-conditioning plant on-line.

Waste Heat Water Circulating Systems

In this section controls and alarms are provided to show the status of major components in the waste heat water circulating system. Pushbutton switches provide start and stop control of the system circulating pumps. Alarms are provided to show three occurrences. These are a high waste heat exchanger outlet temperature condition, a high supplementary electric heater outlet temperature condition, or low water level in the system compression tank. You can obtain indication of the waste heat system pressure and the supplementary heaters outlet temperature on the demand display.

The waste heat exchanger transfers heat generated by the SSDG to the waste heat water circulating system. The waste heat water circulating system supplies heat to the fuel transfer heaters, the fuel service heaters, the L.O. purifier heater, the distilling plants, and the hot potable water accumulator tank heating coil. The system has four waste heat exchangers and four circulating pumps. The pumps start and stop automatically with the starting and stopping of their associated SSDG. The circulating equipment is located in the three auxiliary machinery rooms and the engine room. The system is designed for automatic start-up and unattended operation.

Compressed Air Plants

The status of the HP air system and the LP air system is provided by alarms and visual indicators. Pushbuttons are provided to stop any of the four compressors in an emergency. The alarms alert the operator when the air receiver pressure is low, when the HP system after-cooler temperature is high, when the LP system dryer discharge temperature is high, and when an automatic compressor safety shutdown has occurred. A split-type indicator shows when power is being supplied to the compressor and when the compressor is running.

There are two air plants. Each one has an HP air system and an LP air system. One of the air plants is located in auxiliary machinery room No. 2 and the second is located in auxiliary machinery room No. 3. Each of the four compressed air systems is provided with indicators and a switch

at the ACC. The systems are designed for local start-up and unattended operation.

Main Engines Starting Air System

The starting air compressors in the starting air system are designed for either local or remote start-up. This section provides controls to allow the operator at the ACC to engage or disengage the compressor clutch. For the controls to be operational, the local clutch controller selector switch must be in the REMOTE position. This section also provides indication of the clutch status and alarms for low compressor L.O. pressure and failure of the clutch to engage. A meter provides a continuous reading of the air discharge pressure.

The main engines starting air system provides compressed air to the GT pneumatic starter. The starter rotates the GG for starting, motoring, or water washing. The starting air system uses compressed air supplied from one of three starting air compressors. In an emergency, it can use compressed air from the bleed air system of an operating engine. Only one compressor is used for starting, motoring, or water washing. Two of the compressors are located in auxiliary machinery room No. 2; the third is located in auxiliary machinery room No. 3.

Each starting air compressor is driven by an associated diesel generator set. The compressor is driven by the diesel engine via a step-up gearbox and hydraulic clutch. The clutch can be engaged whenever electrical load on the respective SSDG is below 666 kW. During compressor operation, should kW load on the SSDG exceed 666 kW, the clutch will disengage.

Air-Conditioning Plants

The status of the three air-conditioning plants is provided at the ACC by visual indicators and alarms. Pushbuttons provide the capability for stopping the air-conditioning compressors in an emergency.

The air-conditioning plants provide chilled water for the chilled water circulating system. There are three air-conditioning plants. Each plant can service a separate loop in the chilled water system. Each plant has a rated capacity of 80 tons of refrigeration. The plants are designed for local start-up and unattended operation. One plant is located in the air-conditioning machinery room and two are located in auxiliary machinery room No. 2.

Ship's Stores Refrigeration Plants

The status of the two ship's stores refrigeration plants is provided at the ACC by visual indications and alarms. Pushbuttons provide the operator with the capability of stopping the compressors in an emergency. An indicator provides the operating status of the compressor. Alarms are actuated when an automatic safety shutdown has occurred, when the freeze room temperature is too high, or when an abnormal chill room temperature is detected (high or low).

The ship's stores refrigeration plants allow for the preserving of perishable food stores. The plants serve one freeze room and two chill rooms. Each plant has a rated capacity of 1.1 tons of refrigeration. Both plants are located in auxiliary machinery room No. 1. They are designed for local start-up and unattended operation.

Alarm Acknowledge

The ALARM ACK pushbutton is located in the lower, central portion of the ACC vertical panel. When an out-of-tolerance condition occurs in a system being monitored at the ACC, the associated fault alarm actuates. The audible alarm is accompanied by a flashing visual light. The operator acknowledges the alarm by depressing the ALARM ACK pushbutton. The audible portion of the alarm will be silenced and the visual light will stop flashing but will remain illuminated. The light remains illuminated until the cause of the alarm has been cleared. This pushbutton is used to acknowledge any alarm on the ACC.

Processor Generated Alarm

The processor is a special purpose computer located in the EPCC. When an out-of-tolerance condition occurs on equipment being monitored at the ACC, the equipment sensor transmits a signal to the equipment fault alarm circuitry in the console. The signal also is transmitted to the processor through the ACC. The processor compares the signal with the alarm set value to

determine if an out-of-tolerance condition exists. If the condition does exist, the processor checks the equipment fault alarm circuitry to determine if the fault alarm has been actuated. If the processor detects an alarm condition not provided by the normal fault alarm circuitry, the PROCESSOR GENERATED ALARM indicator will flash and the parameter audible alarm will sound.

Lamp Tests

Two backlighted momentary-action LAMP TEST pushbuttons are provided on the right-hand side of the panel. These are used to test the lamps on the vertical panel.

ACC LOWER PANEL

The ACC lower panel has the switches and indicators that control and monitor the potable water system; the masker, prairie, fin stabilizer, and bleed air systems; the sewage disposal system; the distilling plants; the saltwater service system; and the drainage system. It is shown on figure 10-42, a foldout at the end of this chapter.

Potable Water System

The indicators for the potable water system include tank level meters and indicators for the status of the two potable water pumps and the hot potable water pump. High- and low-level alarms are provided for each of the four tanks. The demand displays can be used to monitor the tank levels and the potable water system pressure. Pushbutton OPEN/CLOSE switches for the potable water tank fill valves allow the operator to coordinate the tank filling operation.

The potable water system stores and distributes brominated water required by the ship's crew and equipment. There are four potable water tanks. The system is served by two centrifugal pumps. Either pump can take suction from any of the four tanks. The pump discharges to either the filling and transfer main or to the service main. The system is designed for local start-up and unattended operation. All the system components being monitored or controlled are located in auxiliary machinery room No. 3.

Distilling Plants

Alarms, lighted indicators, and a pushbutton are provided for monitoring and controlling the operation of the distilling plants. The alarms alert the operator to a high or low temperature of the distillate leaving the sterilizer and to a high distillate salinity condition. A lighted indicator provides the status of the three pumps associated with each distilling plant. A pushbutton allows remote operation of the plant's 3-way solenoid trip valve.

The function of the distilling plants is to supply fresh water for the ship's potable water system. It also supplies untreated distilled water to the gas turbine water wash system, the electronic cooling water system, and the static frequency changers. There are two independent 4,000 gallons per day distilling plants. Both plants are located in auxiliary machinery room No. 3.

Masker, Prairie/Fin Stabilizer, and Bleed Air Systems

Pushbutton switches allow control of the two supply cutout valves in the masker air system and the supply cutout valve in the prairie/fin stabilizer air system. Split-type indicators provide the valve status. A meter allows the operator to continuously monitor the air discharge temperature from the bleed air cooler. An alarm is provided to alert the operator to an air high temperature condition.

Sewage Disposal System

The ACC has alarms and indicators to show the status of the collecting, holding, and transfer (CHT) tank level, the sump ejection tank level, the sewage holding tank air compressor, the macerator sewage pump, the comminutors, and the sewage ejection pumps. The level in the collecting, holding, and transfer tank can be obtained on the demand display.

The sewage disposal system allows for the disposal of waste from the ship to satisfy the prevailing ecology requirements. The system has a CHT tank, two comminutors, and two ejection pumps located in the collecting, holding, and boiler room. It also has the sump ejection tank and macerator sewage pump located in the steering gear room. Soil and waste drains empty into the CHT tank, or directly overboard depending on the location of the drain within the ship. The contents of the sump ejection tank are automatically pumped through the macerator sewage pump to the CHT tank when the ejection tank is filled to 70 percent of capacity. The CHT tank can be emptied by piping directly overboard when in unrestricted waters, to a barge when in restricted waters, or to shore facilities when the ship is secured to a dock. The system is designed for local start-up and unattended operation.

Saltwater Service System

The status of the saltwater service system is provided by meters and an alarm for firemain pressure. Also, there are alarms for the seawater cooling system pressure in the three auxiliary machinery rooms, the engine room, and the air-conditioning machinery room. Pushbutton switches and lighted indicators provide control and status of cooling water overboard discharge valves in the engine room, auxiliary machinery room No. 2, and the air-conditioning machinery room.

Drainage System

The drainage system indicators include alarms indicating a high liquid level in the bilge of each of the eight rooms being monitored, a high level in the waste water drain tanks in the three auxiliary machinery rooms, and a high level in the oily waste water holding tank. Indicators also show the status of the steering gear room drain pump and the bilge pump in auxiliary machinery room No. 2. The demand display may be used to monitor the level in the oily waste water holding tank.

BELL AND DATA LOGGERS

Two automatic loggers are located in the CCS to provide printed copies of plant conditions. These are the data logger and bell-logger.

The data logger (figure 10-43) provides a hard copy printout of selected monitor points. The printout is initiated automatically once every hour; however, an automatic/demand control permits the operator to demand a printout of data when it is needed. If a fault alarm occurs, the data logger also will print out the parameter that caused the alarm. The data logger gives the time in seconds and identifies the monitored sensor.

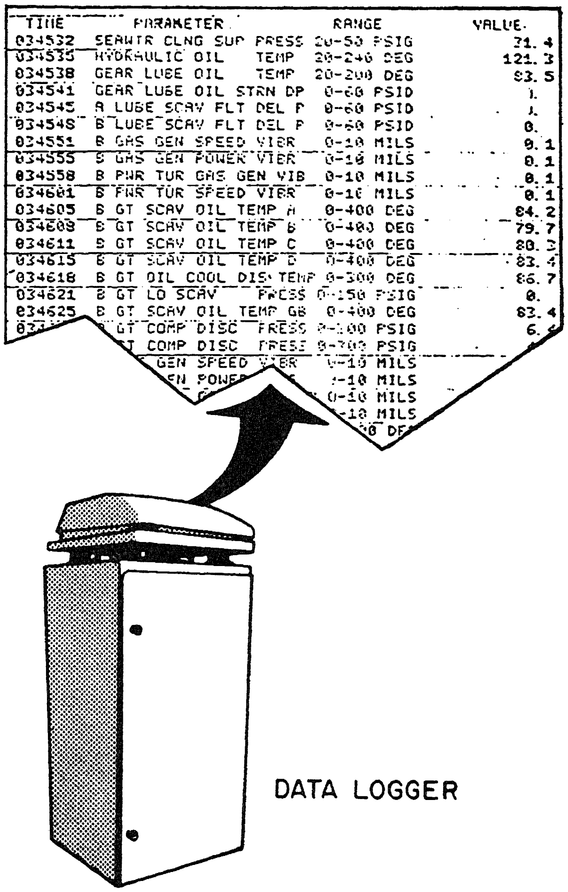

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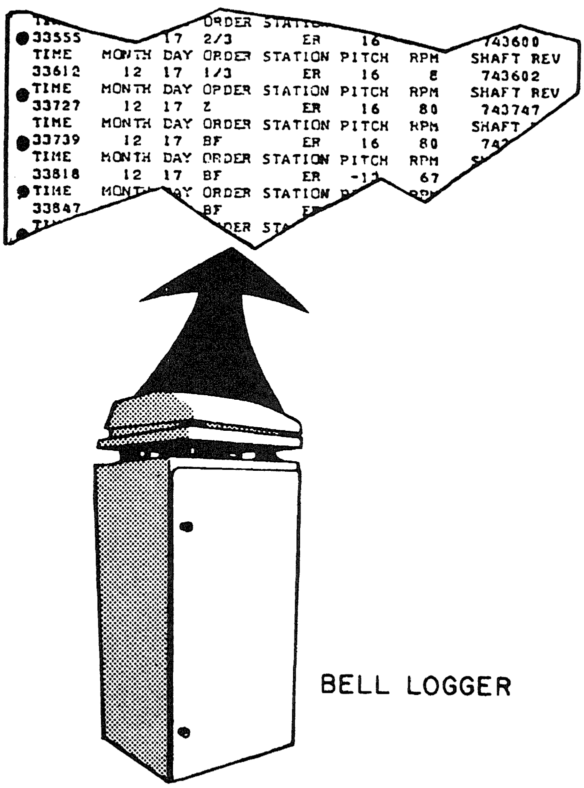
Figure 10-43.—Data logger with sample printout.

The bell logger (figure 10-44) provides an automatic printout each hour or when any of the following events occur.

- Propeller rpm or pitch is changed by more than 5 percent.
- A bell logger printout is demanded by the PCC operator.
- The EOT is changed.
- The controlling station has been changed (bridge or PCC).

The bell logger prints out the following information on a 72-column preprinted page.

- Time
- Month
- Day
- Order
- Station
- Pitch (angle of controllable pitch propeller)
- rpm
- Shaft revolutions



227.37
Figure 10-44.—Bell logger with sample printout.

SUMMARY

This chapter has familiarized you with the operation of the FFG-7 class engineering plant from the CCS. Most GSEs assigned to an *Oliver Hazard Perry* class ship will stand watches at one time or another in the CCS. For this reason, you should be very familiar with the capabilities of the CCS consoles. Like all other material in this RTM, this was written to form a basis to start your qualifications at watch stations on your ship. Even if you are not assigned to an FFG-7 class ship, your knowledge of this material will help you advance in rate and make you more valuable to the Navy.

In no way is this material meant to be a one-stop source for qualifying as an FFG-7 watch stander. You should use the EOSS, the PQS, ship information books, and technical manuals for this process. By combining these sources, you should have no problem becoming a qualified watch stander.

GSEs are also responsible for maintenance of these consoles. Although they are relatively trouble free, you should become familiar with their internal operation. The proposed *GSE 1 & C* RTM should help form a basis for your understanding of this material.

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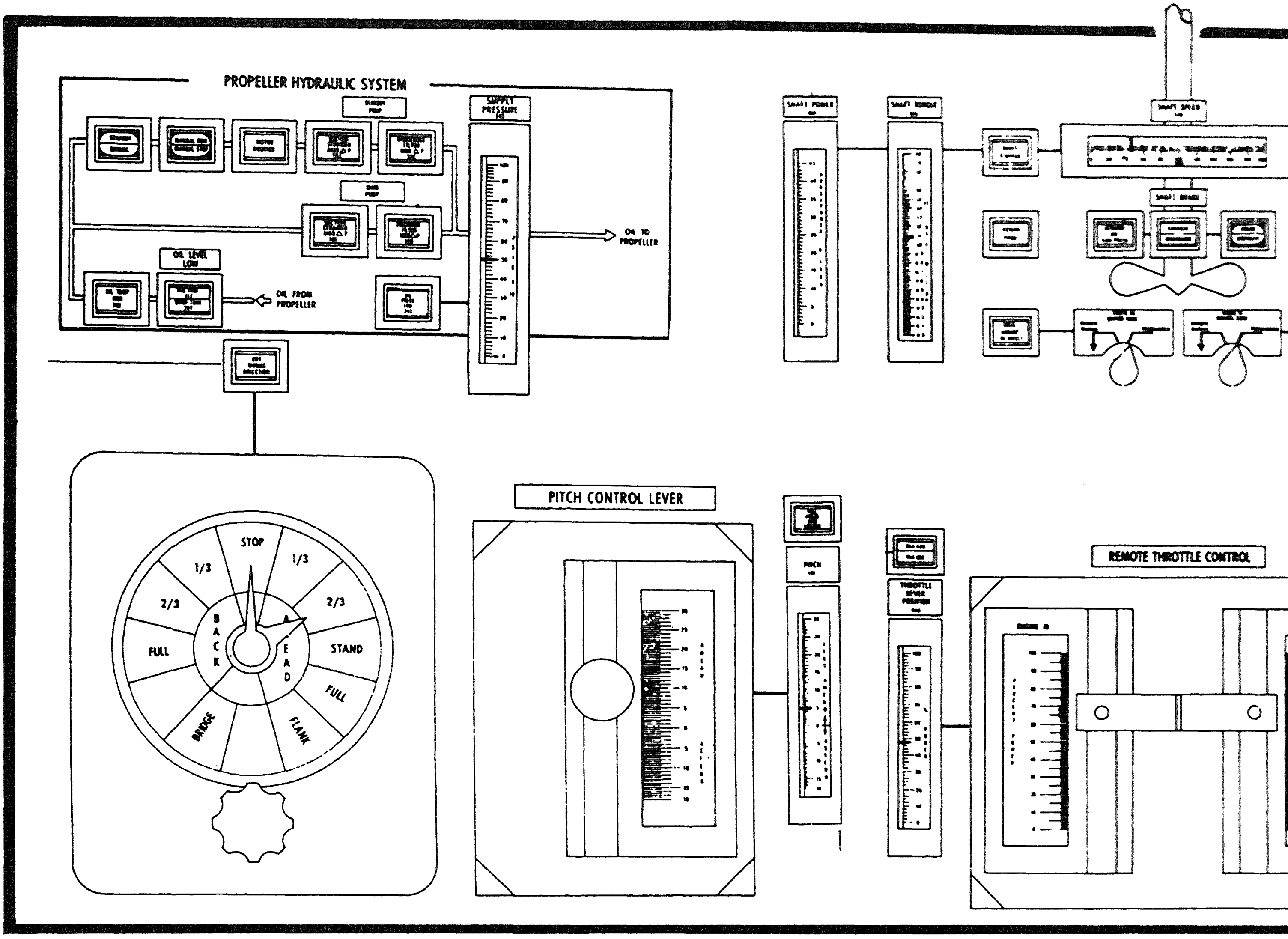

PROPELLER HYDRAULIC SYSTEM
SUPPLY PRESSURE PSI
OIL LEVEL LOW
OIL TO PROPELLER
OIL FROM PROPELLER
STOP
1/3
1/3
2/3
2/3
FULL
STAND
FULL
FLANK
BRIDGE
BACK
AHEAD
PITCH CONTROL LEVER
PITCH
THROTTLE LEVER POSITION
REMOTE THROTTLE CONTROL

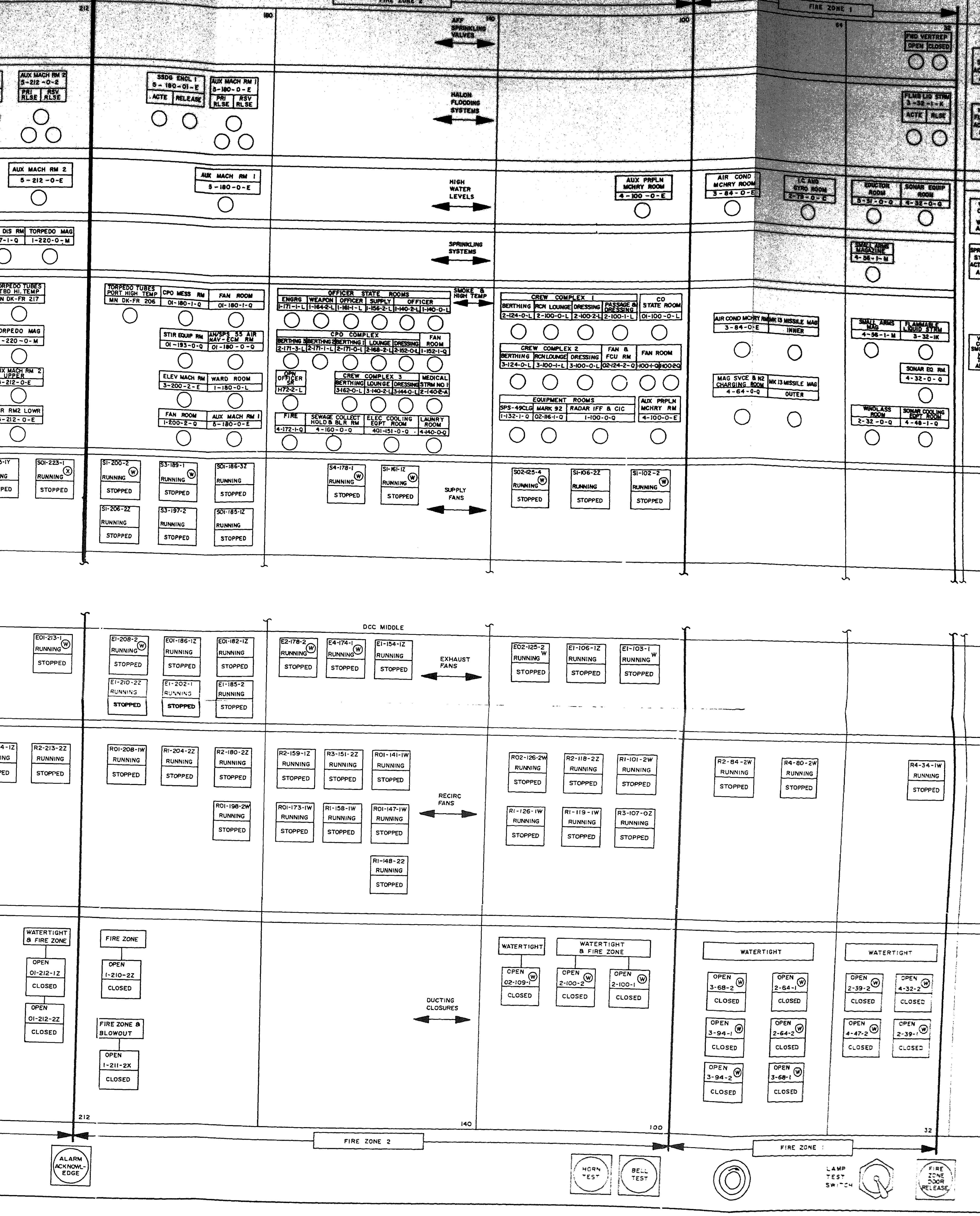
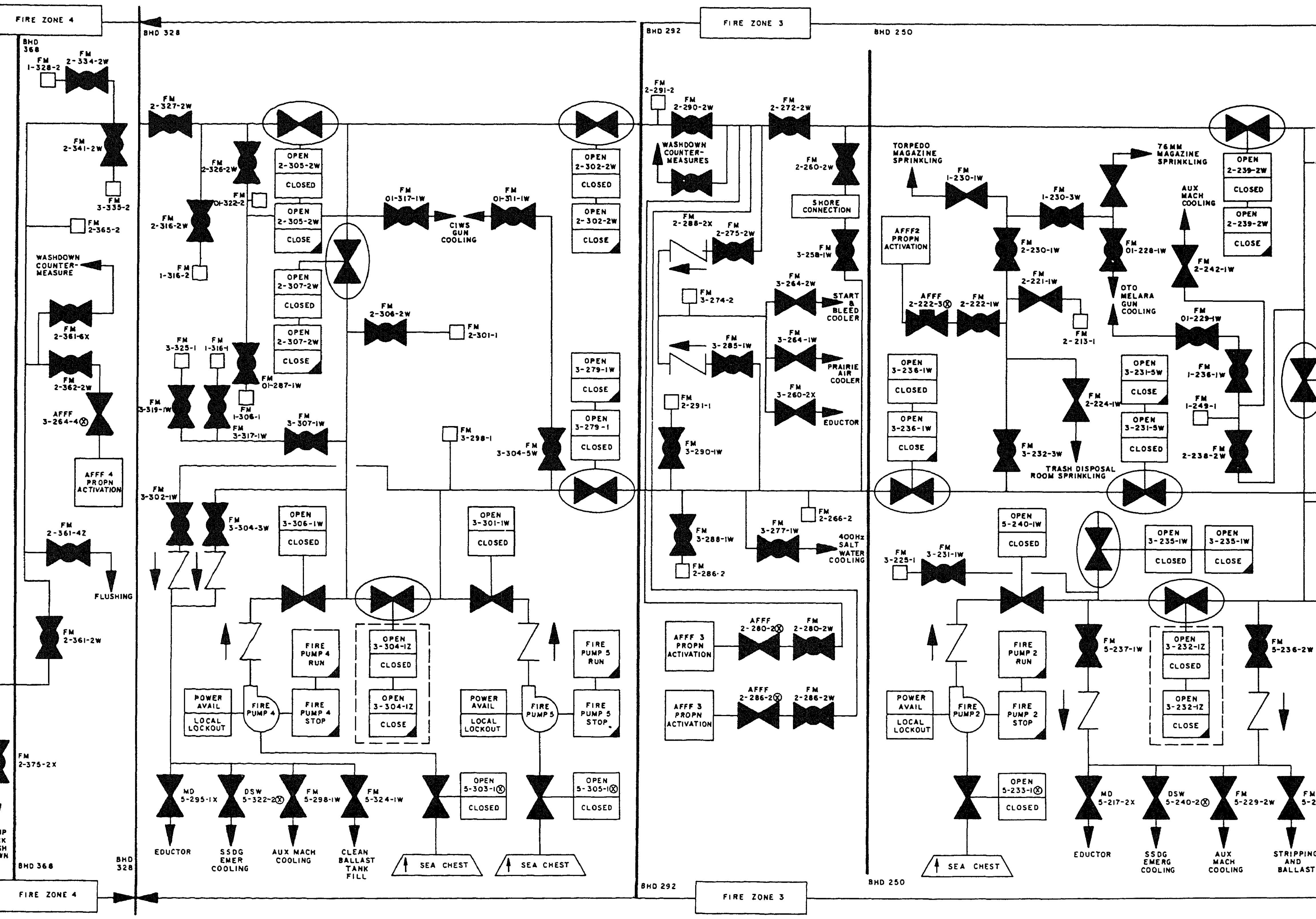


Figure 10-38.—Damage control console upper panel.

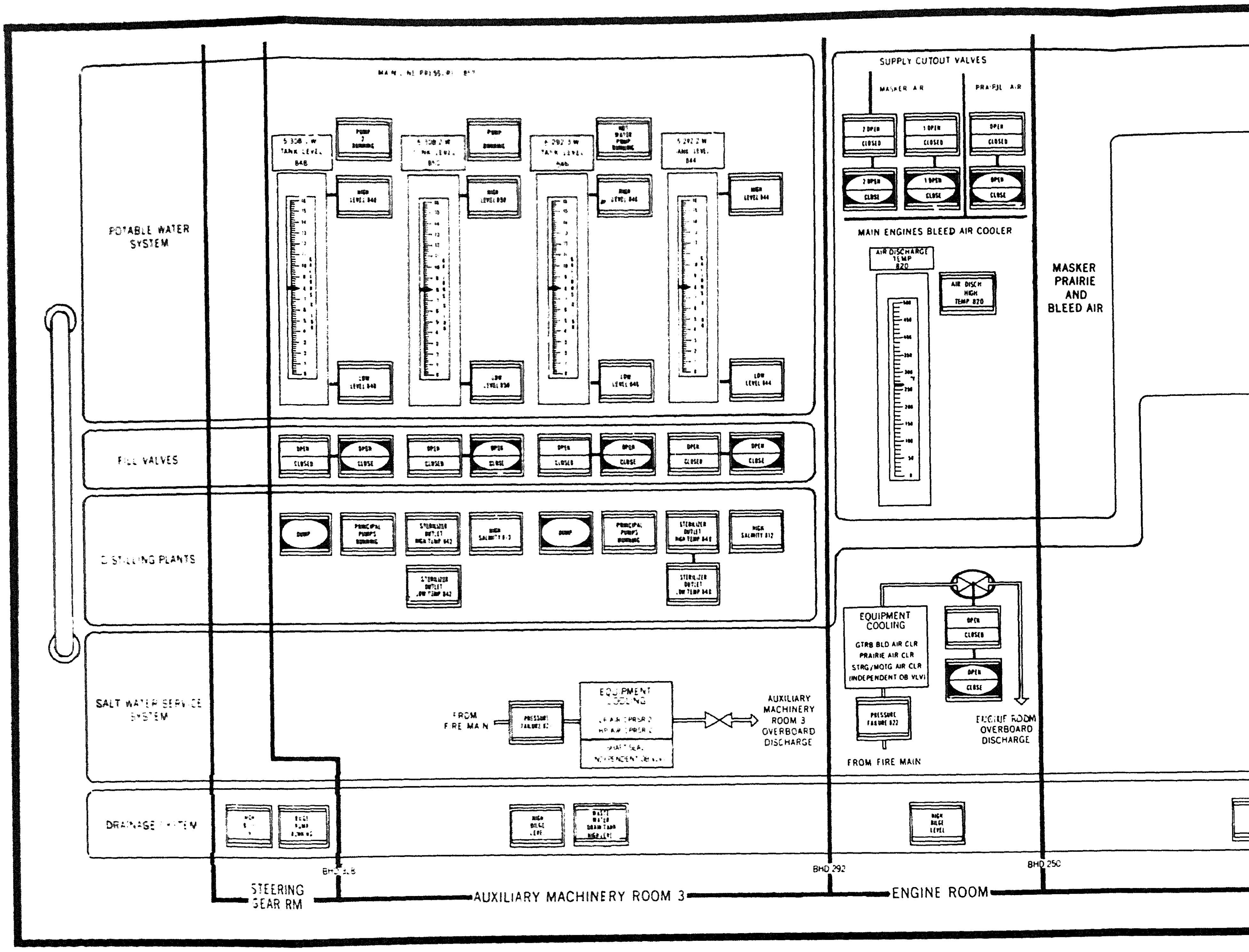

FIRE ZONE 4
FIRE ZONE 3
BHD 368
BHD 328
BHD 292
BHD 250
FM 1-328-2
FM 2-334-2W
FM 2-341-2W
FM 3-335-2
FM 2-365-2
WASHDOWN COUNTER-MEASURE
FM 2-361-6X
FM 2-362-2W
AFFF 3-264-4
AFFF 4 PROPN ACTIVATION
FM 2-361-4Z
FLUSHING
FM 2-361-2W
FM 2-375-2X
FM 2-327-2W
FM 2-326-2W
FM 01-322-2
FM 2-316-2W
FM 1-316-2
OPEN 2-305-2W
CLOSED
OPEN 2-305-2W
CLOSE
OPEN 2-307-2W
CLOSED
OPEN 2-307-2W
CLOSE
FM 01-317-1W
FM 01-311-1W
CIWS GUN COOLING
OPEN 2-302-2W
CLOSED
OPEN 2-302-2W
CLOSE
FM 2-306-2W
FM 2-301-1
FM 3-325-1
FM 1-316-1
FM 01-287-1W
FM 3-319-1W
FM 1-306-1
FM 3-317-1W
FM 3-307-1W
OPEN 3-279-1W
CLOSE
OPEN 3-279-1
CLOSED
FM 3-298-1
FM 3-304-5W
FM 3-302-1W
FM 3-304-3W
OPEN 3-306-1W
CLOSED
OPEN 3-301-1W
CLOSED
FIRE PUMP 4 RUN
FIRE PUMP 4 STOP
OPEN 3-304-1Z
CLOSED
OPEN 3-304-1Z
CLOSE
POWER AVAIL
LOCAL LOCKOUT
FIRE PUMP 4
FIRE PUMP 5
FIRE PUMP 5 RUN
FIRE PUMP 5 STOP
MD 5-295-1X
DSW 5-322-2
FM 5-298-1W
FM 5-324-1W
OPEN 5-303-1
CLOSED
OPEN 5-305-1
CLOSED
EDUCTOR
SSDG EMER COOLING
AUX MACH COOLING
CLEAN BALLAST TANK FILL
SEA CHEST
FM 2-291-2
FM 2-290-2W
FM 2-272-2W
WASHDOWN COUNTER-MEASURES
FM 2-260-2W
SHORE CONNECTION
FM 2-288-2X
FM 2-275-2W
FM 3-258-1W
FM 3-274-2
FM 3-264-2W
START & BLEED COOLER
FM 3-285-1W
FM 3-264-1W
PRAIRIE AIR COOLER
FM 3-260-2X
EDUCTOR
FM 2-291-1
FM 3-290-1W
FM 2-266-2
FM 3-288-1W
FM 3-277-1W
400Hz SALT WATER COOLING
FM 2-286-2
AFFF 3 PROPN ACTIVATION
AFFF 2-280-2
FM 2-280-2W
AFFF 2-286-2
FM 2-286-2W
TORPEDO MAGAZINE SPRINKLING
FM 1-230-1W
FM 1-230-3W
76MM MAGAZINE SPRINKLING
AUX MACH COOLING
OPEN 2-239-2W
CLOSED
OPEN 2-239-2W
CLOSE
AFFF2 PROPN ACTIVATION
FM 2-230-1W
FM 01-228-1W
FM 2-242-1W
FM 2-221-1W
AFFF 2-222-3
FM 2-222-1W
FM 2-213-1
OTO MELARA GUN COOLING
FM 01-229-1W
OPEN 3-236-1W
CLOSED
OPEN 3-236-1W
CLOSE
FM 2-224-1W
OPEN 3-231-5W
CLOSE
OPEN 3-231-5W
CLOSED
FM 1-236-1W
FM 1-249-1
FM 2-238-2W
FM 3-232-3W
TRASH DISPOSAL ROOM SPRINKLING
OPEN 5-240-1W
CLOSED
OPEN 3-235-1W
CLOSED
OPEN 3-235-1W
CLOSE
FM 3-225-1
FM 3-231-1W
FM 5-237-1W
OPEN 3-232-1Z
CLOSED
OPEN 3-232-1Z
CLOSE
FM 5-236-2W
FIRE PUMP 2 RUN
FIRE PUMP 2
FIRE PUMP 2 STOP
OPEN 5-233-1
CLOSED
MD 5-217-2X
DSW 5-240-2
FM 5-229-2W
SSDG EMERG COOLING
AUX MACH COOLING
STRIPPING AND BALLAST

A4

A3

B4

B3


POTABLE WATER SYSTEM
FILL VALVES
DISTILLING PLANTS
SALT WATER SERVICE SYSTEM
DRAINAGE SYSTEM
SUPPLY CUTOUT VALVES
MASKER AIR
PRAIRIE AIR
MAIN ENGINES BLEED AIR COOLER
AIR DISCHARGE TEMP 820
AIR DISCH HIGH TEMP 820
MASKER PRAIRIE AND BLEED AIR
EQUIPMENT COOLING
GTRB BLD AIR CLR
PRAIRIE AIR CLR
STRG/MOTG AIR CLR
(INDEPENDENT OB VLV)
PRESSURE FAILURE 822
FROM FIRE MAIN
ENGINE ROOM OVERBOARD DISCHARGE
FROM FIRE MAIN
AUXILIARY MACHINERY ROOM 3 OVERBOARD DISCHARGE
BHD 292
BHD 250
STEERING GEAR RM
AUXILIARY MACHINERY ROOM 3
ENGINE ROOM

A4

A3

B4

B3

CHAPTER 11

UNINTERRUPTIBLE POWER SUPPLY

Periodically a gas turbine ship experiences a partial or total loss of 60-Hz ship's service power to engineering equipment requiring a constant power source. The equipment may be a control console, a switchboard, or a GTE. Most control consoles cannot withstand an interruption of the power that feeds them. The LM2500 will shut down if power is removed from the fuel valve solenoids. Therefore, these vital engineering functions must be maintained for a short period of time during a power interruption.

To provide power for vital pieces of equipment during short-term operation, gas turbine ships are designed with battery backup systems. This battery backup provides an alternate source of power upon failure of ship's service power. Because these systems need an immediate standby source of power, they must have a very rapid method of transferring the load to the backup. This is done by the use of static (or electronic) switching. The shift from failing 60-Hz power to the battery backup is very rapid. It is an uninterrupted shift. Therefore, the battery backup system is commonly known as an uninterruptible power supply (UPS).

All propulsion electronics rely on 115/120-volt a.c. as the input to their power supplies. The UPS battery systems for these consoles must provide power in that range. Batteries are normally a low-voltage power source. This means several batteries must be placed in series to obtain the proper voltage levels. We will refer to this group of batteries as a battery bank.

As a GSE, you will be required to maintain these battery banks along with their associated chargers. All the batteries used in UPS systems are wet-cell types. Their maintenance requirements are special. We will discuss battery safety precautions in this chapter.

Sometimes an a.c. voltage is required when you use a d.c. input source. This a.c. is produced by an inverter. We will also discuss the uses and function of inverters in this chapter.

Like previous chapters, we will break down the differences between the FFG-7 class and the twin-shaft gas turbine ships. This is because the UPS system is different on each type of gas turbine ship design.

Upon completion of this chapter and its associated NRCC, you should be able to understand the functions and purposes of the UPS system. You should be able to discuss battery construction and maintenance, how to use a hydrometer, and the safety precautions used when working on batteries. You should also be able to understand and describe the use and function of inverters. The principles and uses of rectifiers and battery chargers are discussed in this chapter. After studying this chapter, you should be able to understand their operation.

Remember, any time you work on unfamiliar equipment, consult an experienced technician or the proper technical manual. This will help to ensure that you know the safety steps needed. You should be prepared and avoid hurting yourself, your shipmates, or any vital piece of ship's equipment.

UNINTERRUPTIBLE POWER SUPPLY

The UPS system is designed to provide a constant source of power to vital engineering equipment. As a GSE, you may be exposed to one of two types of UPS designs. The UPS used on the FFG-7 class ship is the normal source of power

for the propulsion electronics. It does not employ the batteries all the time, but the UPS equipment is the normal source for console power. We will discuss this system in depth later in this section.

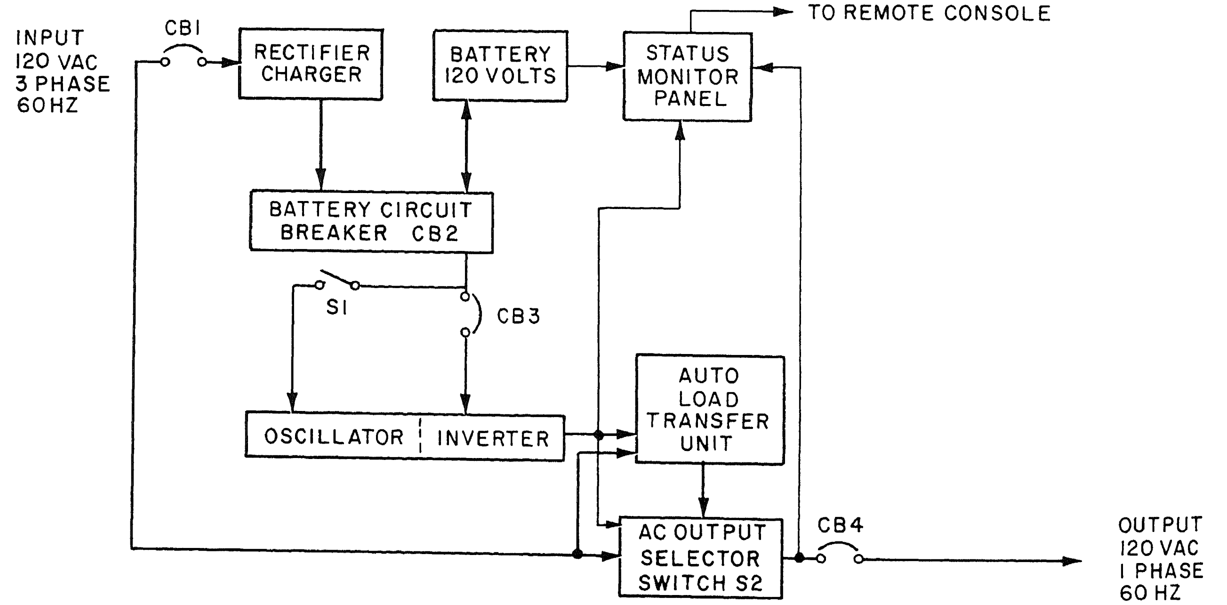
The DD-963, DDG-993, and CG-47 classes use a slightly different concept for supplying uninterrupted power to consoles. On these ships the normal supply of power is from the ship's service 120-volt a.c., 60-Hz bus. Power is also fed to the electronics from the 150-volt d.c. UPS battery bank. All switching for this system is done in the propulsion electronics. These classes also have battery backup for each switchboard and GTGS. The battery supply is an uninterruptible system but is NOT commonly referred to as UPS.

FFG-7 UPS SYSTEM

The UPS system on the FFG-7 has a UPS unit and 20 lead-acid batteries. The UPS unit and the batteries are located in the MER. The output of the UPS unit is the normal source of power for the propulsion electronics. This output is rated at 7.5 kW at 120-volt, 60-Hz, single-phase a.c. The input to the UPS unit is 3-phase, 120-volt, 60-Hz a.c.

It may be confusing that the input and output of the UPS unit are the same. Inside the unit d.c. voltage must be produced for battery charging. This d.c. must also be converted back to a.c. for use by the propulsion electronics. Likewise, switching must be provided to make the transfer to battery power uninterrupted.

Figure 11-1 is a block diagram of the UPS unit used on the FFG-7 class ship. The unit consists of the following major components: a rectifier charger, a battery circuit breaker, an oscillator/inverter, a status monitor panel, an auto load transfer unit, and an a.c. output selector switch. The 120-volt battery bank is external to the unit and will be discussed later. Several circuit breakers are installed in the UPS unit. They are used as disconnects during maintenance and isolation of the UPS unit.



293.1

Figure 11-1.—Overall block diagram, FFG-7 UPS system.

Rectifier Charger

The rectifier charger is used to charge the battery bank while maintaining a source of power to the oscillator/inverter. Figure 11-2 is a block diagram of the rectifier charger.

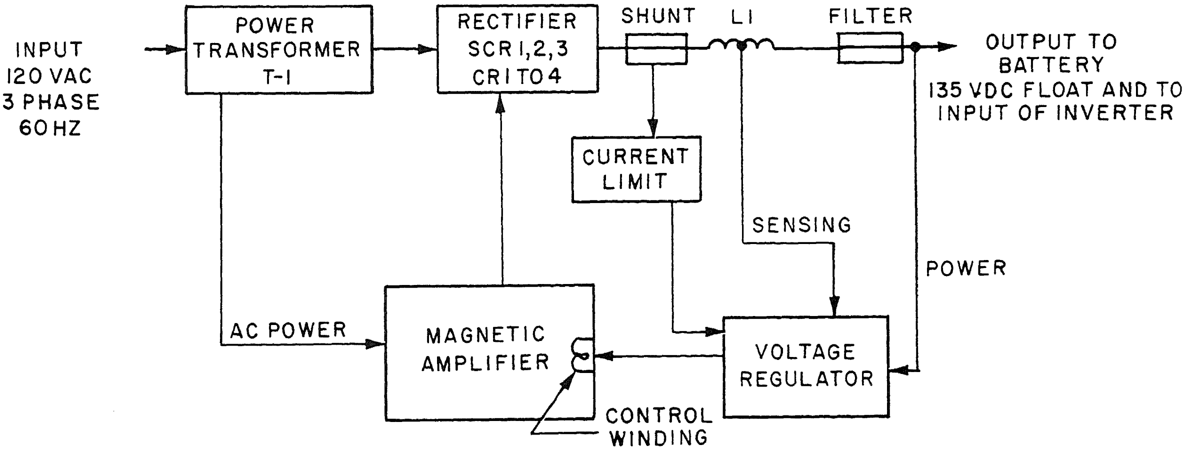
The input to the rectifier is 120-volt, 60-Hz, 3-phase ships' service a.c. power. This power is brought into a wye-delta type transformer (XFMR) T-1. The a.c. power from the secondary delta windings of XFMR T-1 is then applied to a 3-phase rectifier bridge and the a.c. power windings of the magnetic amplifier. The rectifier bridge consists of rectifiers CR-1 through CR-4 and SCR-1 through SCR-3. The magnetic amplifier controls the SCRs in response to a voltage change sensed across the load. This sensing is done by filter choke L1 and the voltage divider network (R14, R4, and R5 not shown) that inputs to the voltage regulator. An increase in current flow of positive feedback in the control windings will increase the magnetic amplifier output. This will cause SCR-1 through SCR-3 to trigger earlier and will increase the output voltage of the supply. Conversely, an increase in current flow of negative feedback in the control windings will cause a later trigger of the SCRs. It will also decrease the output voltage of the supply. These same voltage regulator controls will control and limit the current when the rectifier is used as a battery charger. When the load on the rectifier is a fully discharged battery bank, the current limiting circuit controls the output of the rectifier. It does this by placing a false overvoltage signal to the input of the voltage regulator circuit. This is done when the load current to the batteries exceeds 90 amperes. The circuit responds as it would for a normal overvoltage condition. The SCRs conduct less current and the output of the rectifier is limited to about 90 amperes.

Battery Circuit Breaker

The battery circuit breaker (CB2) is rated at 250-volt, 100-amp d.c. It is an AQB-A101 type of circuit breaker. CB2 is used to disconnect the battery bank from the output of the rectifier charger and the input of the oscillator/inverter.

Oscillator/Inverter

The oscillator/inverter or inverter is used to convert the d.c. voltage from the rectifier or batteries to usable single-phase, 120-volt, 60-Hz



293.2

Figure 11-2.—Block diagram, rectifier/battery charger.

a.c. power. Figure 11-3 is a block diagram of the inverter. The major components are the input circuit breaker, the input choke, the single-phase bridge inverter, the main power and filter network, and the output reactor. It also includes the oscillator assembly with the auxiliary regulator and 60-Hz control XFMR, the SCR driver/steering circuit assembly with the pulse forming board, and the voltage regulator circuit with the current limiting and slow release circuits.

The input circuit breaker (CB3) is a 250-volt, 100-amp d.c. circuit breaker. It is an NQB-A101 type of breaker. It is used to disconnect the inverter from the d.c. input voltage for maintenance.

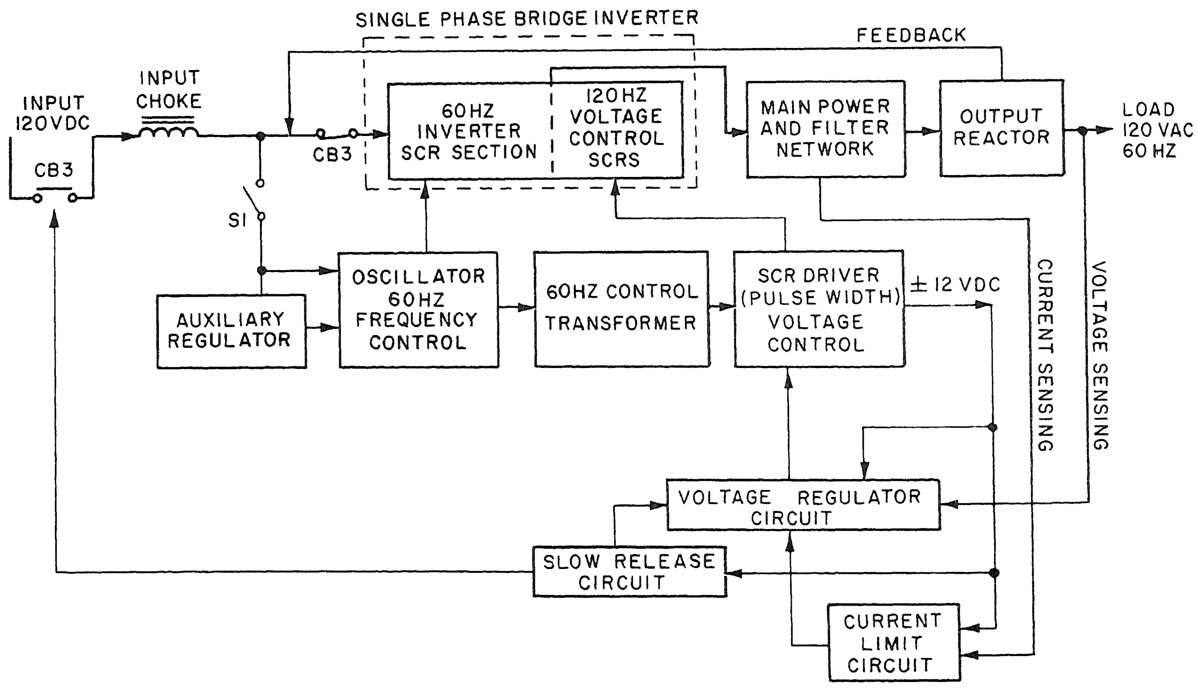
The input choke slows down current surges that may occur when the SCRs are turning ON or OFF. This gives the SCRs time to recover their forward blocking characteristics.

The single-phase bridge inverter contains the 60-Hz inverter SCR section and the 120-Hz voltage control SCRs. Each section has two SCRs. The 60-Hz section forms the basic inverter frequency (60 Hz). The 120-Hz section is used to control the magnitude of the 60-Hz voltage. The 60-Hz section is controlled by the oscillator 60-Hz frequency control. The SCR driver circuit controls the SCRs in the 120-Hz inverter. The inverter output voltage is controlled by varying the firing time of these SCRs.

The main power filter section is used to make a sine wave output voltage. The output of the inverter is transformed into the filter network at a low voltage. The filter uses a low voltage to reduce the size of the capacitor network. The output of this capacitor network is transformed by the output reactor which reduces the output to 120-volt, 60-Hz a.c.

The auxiliary regulator provides a constant voltage (135-volt d.c.) to the input of the 60-Hz oscillator. Its purpose is to boost and regulate the nominal 120-volt d.c. input through switch S-1 to the required regulated 135-volt d.c.

The oscillator 60-Hz frequency control controls the firing of the SCRs in the 60-Hz inverter section. The output of the oscillator is sent also



293.3

Figure 11-3.—Block diagram, oscillator/inverter section.

to the 60-Hz control XFMR. This XFMR provides power to supply the basic square wave 60 Hz required by the SCR driver. The SCR driver assembly performs three functions. These are pulse forming, supply of 12-volt d.c. to the voltage regulator and current limiter, and SCR driving. Pulse forming is done by an integrated circuit. The input of the pulse forming circuit is from the control XFMR. The integrated circuit controls a pair of SCR driver transistors. These SCR driver transistors control the firing of the SCRs in the 120-Hz inverter.

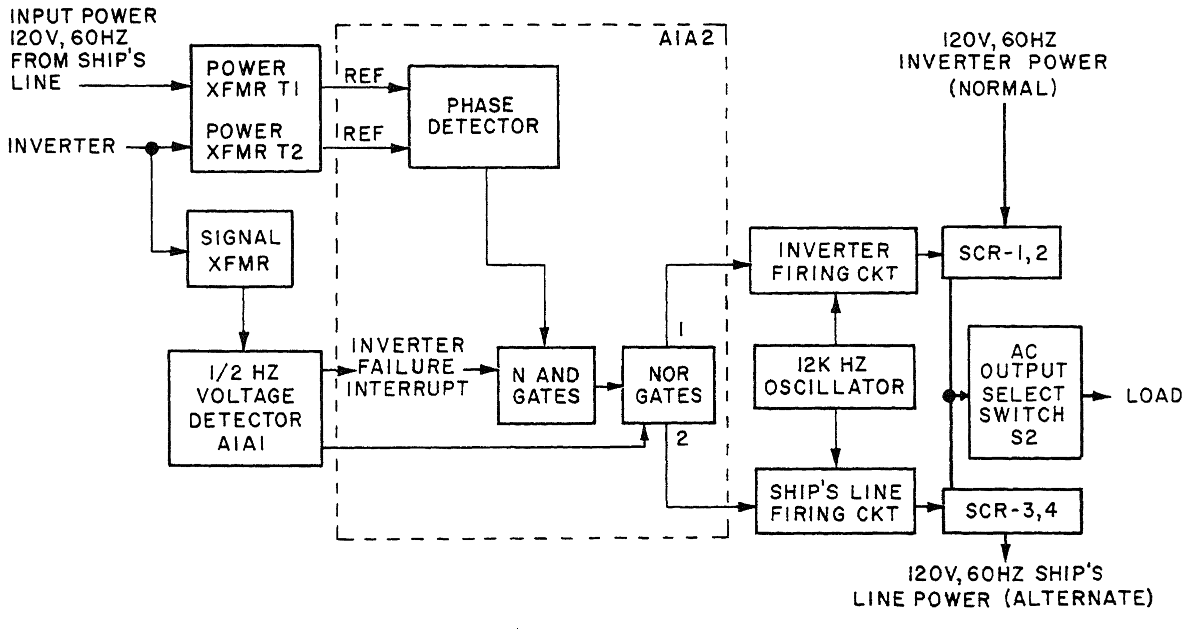
The 12-volt d.c. power supply is also fed from the control transformer. It is a full-wave bridge rectifier and filter-type power supply. The output of the supply is used by the pulse forming circuit and the voltage regulator and current limiter.

The voltage regulator provides steady state voltage regulation for the inverter output. The voltage regulator is completely solid state. It uses a digital to analog voltage detector on the input and an amplifier transistor on the output. Voltage is sensed across the output of the inverter. The output of the voltage regulator is sent to the SCR driver to control the 120-Hz oscillator. The current limiting circuit also inputs to the voltage regulator. It limits the output current of the inverter to 90 amperes. The current limit output causes the voltage regulator to respond as it would to an overvoltage condition. The voltage regulator then controls the SCR driver which decreases the output of the driver to below 90 amperes.

The slow release or soft start circuit achieves a slow buildup of inverter output when the inverter is energized. It also allows a slow decrease in the output when the inverter is de-energized.

Automatic Load Transfer Unit

The automatic load transfer unit provides an uninterrupted transfer of power from the inverter to ship's service 60 Hz during inverter failure. Figure 11-4 is a block diagram of the automatic load transfer unit. The transfer unit will detect an inverter failure and switch to ship's power in under 9 milliseconds. When the inverter is placed back into operation, the unit will shift back to inverter power.



293.4

Figure 11-4.—Block diagram, auto load transfer unit.

The control element of the unit is the 1/2-Hz voltage detector. It measures each 1/2 Hz of the inverter output. It determines if the inverter output is good 60-Hz power. If the output is good, it will cause SCRs 1 and 2 to trigger and connect the load to the inverter. If the output is bad, or not stable 60-Hz power, SCRs 3 and 4 will trigger. This connects the load to ship's service 60 Hz. When the inverter output is again stable at 60 Hz, the control element will trigger SCRs 1 and 2. This shifts the load back to the inverter output.

The phase detector senses the in-phase or out-of-phase conditions between the inverter output and ship's service power. This ensures that a smooth transfer of power occurs when switching from one power source to the other. The phase detector with the NAND and NOR gates and the 1/2-Hz voltage detector provides this synchronization.

The 12K Hz oscillator controls the triggering of the SCRs. Its output is sent to the firing circuits. This ensures a smooth transfer of power by synchronizing the triggering of the SCRs with the inverter output and the ship's service power.

The a.c. output select switch is a manual selector used to override the automatic load transfer unit. This switch is mounted on the panel of the UPS cabinet. It allows the operator to manually select inverter or ship's service power.

Battery Bank

The FFG-7 UPS system uses a bank of 20 6-volt d.c. lead-acid batteries. These batteries are connected in series to provide an output of 120-volt d.c. The bank is housed in an enclosure that vents the gases built up during charging. This enclosure is located in the MER. We will discuss the construction and maintenance of batteries later in this chapter.

DD-963, DDG-993, AND CG-47 UPS SYSTEMS

The twin-shaft gas turbine ships use a much different method for supplying uninterruptible power to the propulsion consoles. Normal power for the electronics on these ships is ship's service 115-volt a.c. They are fed this power from standard power panels served by automatic bus transfers (ABTs). The backup source of power is 150-volt d.c. fed from the UPS battery bank. All power switching for the electronics is done in the power supply cabinets (electronic enclosures). The batteries are normally on a trickle charge from the UPS battery charger. This charger, the battery bank, and the UPS distribution panel are located in the UPS battery room. This room is located above auxiliary machinery room No. 1. Monitoring of the UPS system is done at the EPCC. Figure 11-5 shows the UPS power system used on the twin-shaft ships.

Battery Charger

The battery charger is used for initial charge of the batteries and to recharge the batteries after use. It is also used to maintain a floating or trickle charge on the bank. This is to ensure the batteries are always in a high state of charge.

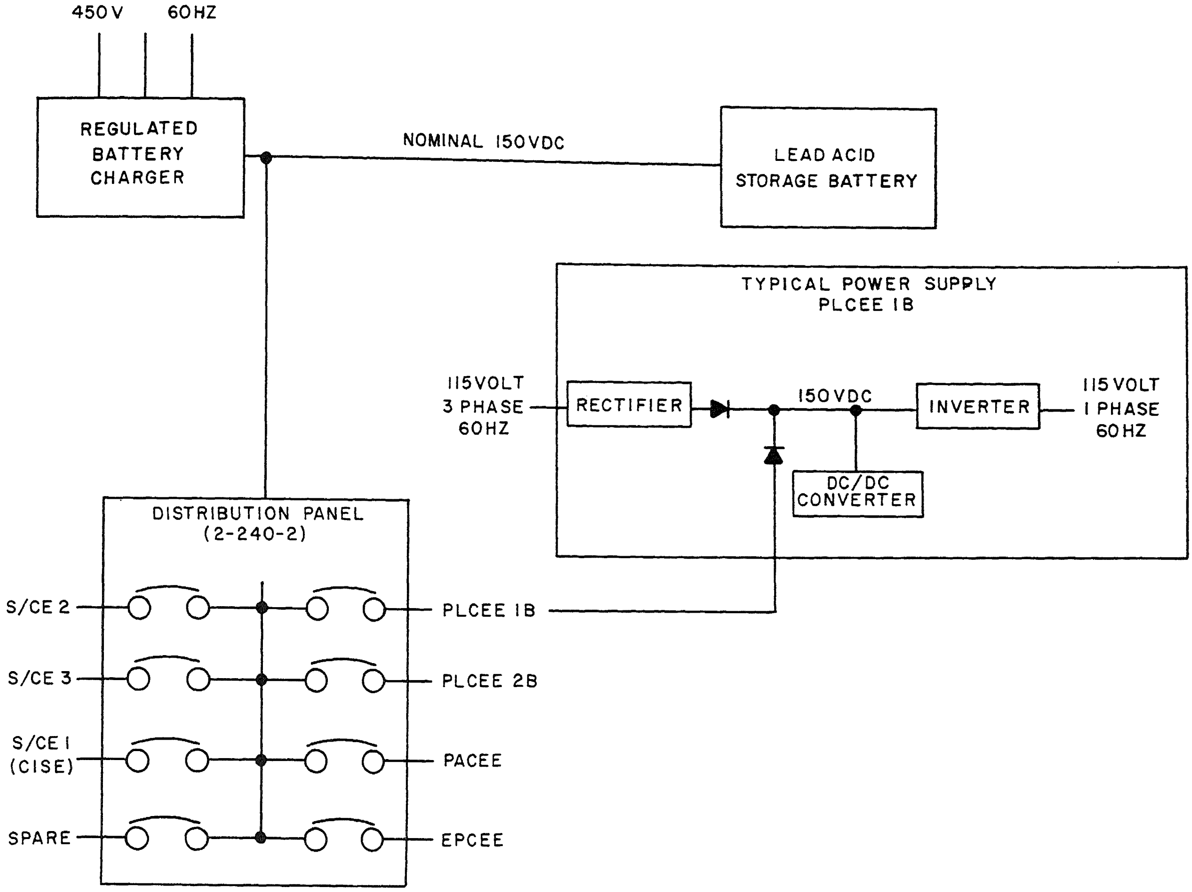
The charger is a fairly standard type of battery charger. It transforms and rectifies the ship's service 450-volt a.c. to 150-volt d.c. for battery charging. The charger has circuitry to limit the output to about 30 amperes. This unit is capable of charging a fully discharged battery bank in 8 hours. The charger front panel has all the meters and controls needed to operate the charger. An interlock is installed into the controls of the unit. It will shut off the charger if ventilation is secured to the UPS battery room. When ventilation is restored, you have to manually restart the charger.

UPS Battery Bank

Nine lead-calcium storage batteries are installed in the UPS battery room. Normal operation requires only eight of these batteries. The ninth battery is a spare. It is normally dry charged. These batteries are capable of powering all the ECSS consoles (except the SCC) for about 30 minutes. The battery bank requires maintenance normally associated with lead-acid batteries. We will discuss lead-acid batteries later in this chapter.

Distribution Panel

The UPS distribution panel is also located in the UPS battery room. It is a standard power panel with eight circuit breakers. Voltage sensing for the UPS voltage meter on the EPCC is done in



293.5

Figure 11-5.—Twin-shaft ship uninterruptible power supply system.

the distribution panel. Two fuses on the panel are in the output that is fed to this meter. The distribution panel feeds the following equipment: signal conditioning enclosures (S/CEs) 1, 2, and 3, electric plant control electronic enclosure (EPCEE), propulsion auxiliary control electronic enclosure (PACEE), and propulsion local control electronic enclosures (PLCEEs) 1B and 2B. The power fed to PLCEEs 1B and 2B is also fed to PLCEEs 1A and 2A and the two FSEEs.

Electronic Enclosures

The electronic enclosures (or power supplies) contain the components used for switching from ship's service power to UPS power. Normal ship's service 115-volt a.c. and 150-volt d.c. UPS is supplied to the power supply cabinet. Each cabinet has a built-in circuit breaker for each source of power. Some of the smaller power supplies, such as the EPCEE, have two separate power supplies in one enclosure. These cabinets will have two circuit breakers for 115-volt a.c. and two for 150-volt d.c. One is for each power supply.

The 115-volt a.c. is then rectified. The output of this rectifier is 150-volt d.c. Two diodes are used for uninterrupted switching of power sources. The output of the rectifier will forward bias the diode on its output line. This is done because the output voltage of the rectifier is slightly higher than the output voltage of the UPS batteries. This causes the diode on the battery line to reverse bias. This keeps the UPS batteries from

supplying any power. If a loss of normal ship's service power occurs, the output voltage of the rectifier will fall below that of the UPS battery voltage. The diode on the UPS line will forward bias supplying UPS battery power to the power supplies. The diode on the rectifier will then reverse bias and prevent a backflow of power into the rectifier.

The power supplies are fed from the output of these two diodes. Several different power supplies are used to convert the 150-volt d.c. to the many different voltage levels used in the consoles. This 150-volt d.c. is also sent to an inverter. This inverter converts the 150-volt d.c. to single-phase, 115-volt a.c., 60-Hz power. This a.c. powers the fans that cool the power supplies.

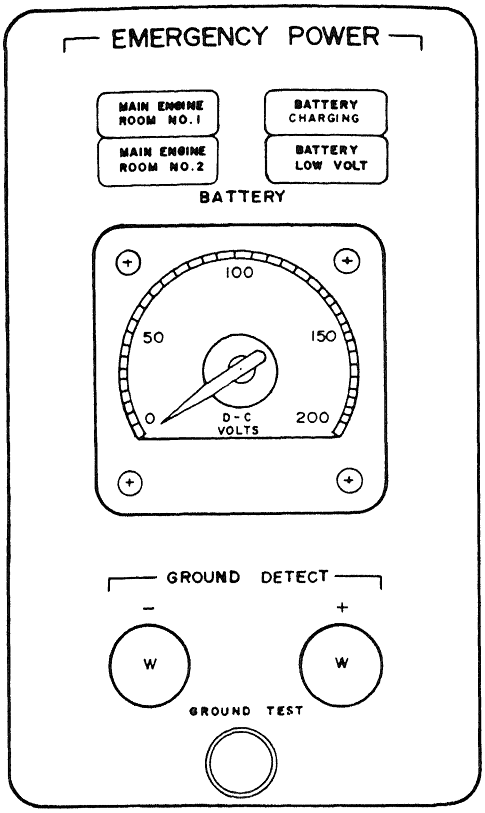
A current sensor is installed on the battery input line. When current flow through these sensors exceeds 0.5 amperes, an alarm will sound on the console. The alarm indicates that the console is on UPS power.

UPS Monitoring

The UPS system is normally monitored at the EPCC. A section of the EPCC (figure 11-6) has a voltage meter, a ground detector, and four UPS alarms. These alarms are BATTERY CHARGING, BATTERY LOW VOLT, MAIN ENGINE ROOM NO. 1, and MAIN ENGINE ROOM NO. 2.

The battery charging alarm will sound when current drawn from the battery charger exceeds 0.5 amperes. This indicator will remain on flashing while charger current exceeds 0.5 amperes. The battery low-voltage alarm will activate when the UPS voltage drops to 122 ± 2 volts d.c. The alarms for MERs No. 1 and No. 2 will illuminate when one of the power supplies in the engine rooms is on UPS power.

The voltage meter displays the d.c. voltage at the distribution panel. The ground detector pushbutton and associated indicator lamps detect a ground in the UPS system. When the pushbutton is depressed and no difference is noted between the brightness of the two lamps, no



293.6
Figure 11-6.—UPS system monitoring section at EPCC.

grounds are detected in the system. If one of the lamps is dimmer than the other, a ground exists. It will be in the positive or negative part of the UPS, whichever lamp is dimmer.

SWITCHBOARD BATTERY BACKUP

The electrical distribution system of the twin-shaft gas turbine ships also use a battery backup. The battery controls circuits of the 60-Hz switchboard and GTGS LOCOP. Each switchboard has an independent battery bank of four 6-volt d.c. lead-acid batteries. These batteries are normally trickle charged by the output of the switchboard 28-volt d.c. power supply. The power supply may fail or the input 450-volt a.c. may be lost. Then the battery power will automatically supply the d.c. power used to control the switchboard and operate the GTGS. The switching is done statically by a set of diodes. This provides uninterrupted

power for the switchboard and GTGS. Figure 11-7 is a diagram of the switchboard battery backup on the twin-shaft type of ships.

Alarms on the switchboard and at the EPCC alert the operators when the switchboard is on batteries. The battery backup is designed to provide power for over 30 minutes of switchboard and GTGS operations.

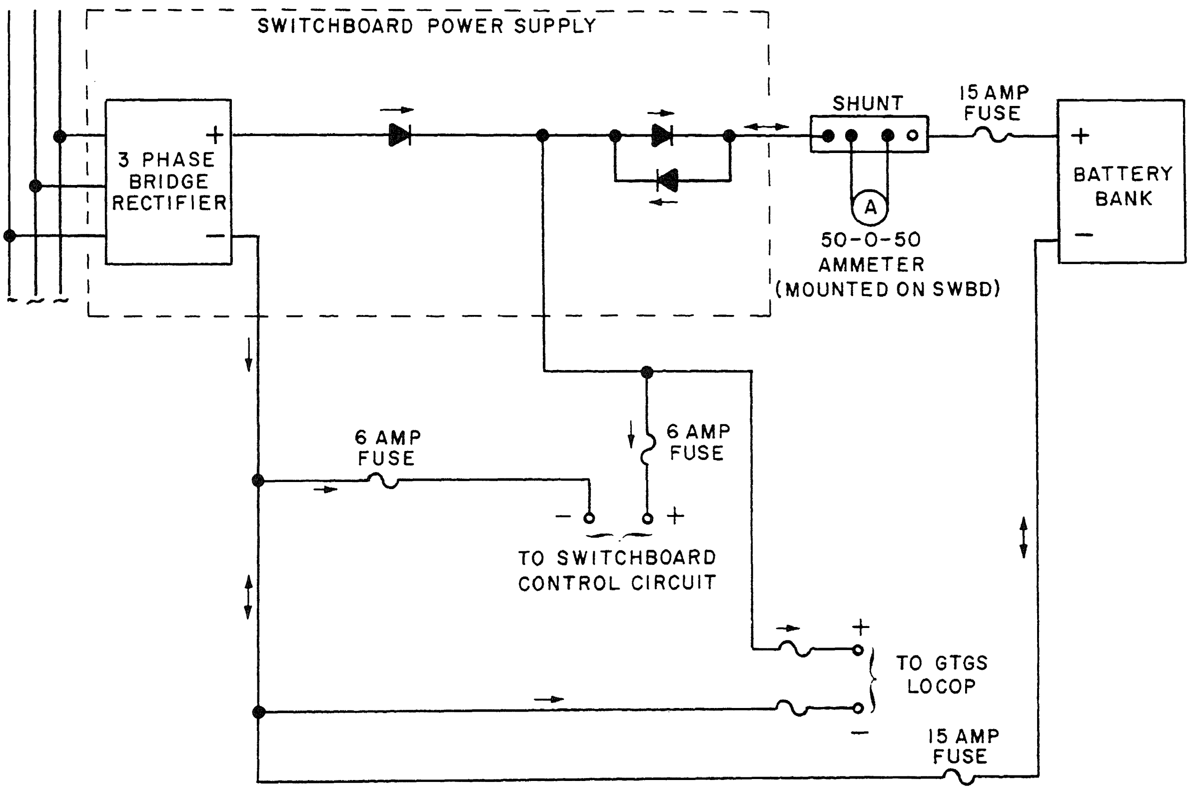
LEAD-ACID STORAGE BATTERIES

Storage batteries provide the power source for the UPS battery system. Periodic inspection of the storage battery is essential in maintaining maximum efficiency and long life of the battery. Batteries used for UPS systems are subjected to moderately heavy use. They require frequent charging by the UPS battery charger or rectifier.

SPECIFIC GRAVITY

The ratio of the weight of a certain volume of liquid to the weight of the same volume of water is called the specific gravity of the liquid. The specific gravity of pure water is 1.000. Sulfuric acid has a specific gravity of 1.830; thus, sulfuric acid is 1.830 times as heavy as water. The specific gravity of a mixture of sulfuric acid and water varies with the strength of the mixture from 1.000 to 1.830.

As a storage battery discharges, the sulfuric acid is depleted. The electrolyte is gradually converted into water. This action is a guide in deciding the state of discharge of the lead-acid cell. The electrolyte usually placed in a lead-acid battery has a specific gravity of 1.350 or less. Generally, the specific gravity of the electrolyte in standard storage batteries is adjusted between 1.210 and 1.260.



293.7

Figure 11-7.—Switchboard battery backup.

Hydrometer

The specific gravity of the electrolyte is measured with a hydrometer. Hydrometers have been discussed in chapter 2. You can also find additional information about hydrometers in *Shipboard Electrical Systems,* NAVEDTRA 10864-D. In the syringe-type hydrometer (figure 11-8), part of the battery electrolyte is drawn up into a glass tube. This is done by a rubber bulb at the top.

The hydrometer float has a hollow glass tube weighted at one end and sealed at both ends. A scale calibrated in specific gravity is laid off axially along the body (stem) of the tube. The hydrometer float is placed inside the glass syringe. Then the electrolyte is drawn up into the syringe. This immerses the hydrometer float into the solution. When the syringe is held almost in a vertical position, the hydrometer float sinks to a level in the electrolyte. The amount the hydrometer stem protrudes above the level of the liquid depends upon the specific gravity of the solution. The reading on the stem at the surface of the liquid is the specific gravity of the electrolyte in the syringe. Thus the specific gravity of the electrolyte in the syringe shown in figure 11-8 would be 1.250 if the temperature is 80 °F.

The Navy uses two types of hydrometer bulbs, or floats, each having a different scale. The type-A hydrometer is used with submarine batteries. It has two different floats with scales from 1.060 to 1.240 and from 1.120 to 1.300. The type-B hydrometer is used with portable storage batteries and aircraft batteries. It has a scale from 1.100 to 1.300. When taking a reading, ensure that the electrolyte in a cell is at the normal level. If the level is below normal, you cannot draw enough fluid into the tube to cause the float to rise. If the level is above normal, there is too much water. Then the electrolyte is weakened, and the reading is too low. A hydrometer reading is inaccurate if you take it immediately after water is added. This is because the water tends to remain at the top of the cell. When water is added, charge the battery for at least an hour. This will mix the electrolyte before the hydrometer reading is taken.

CAUTION

After use, flush hydrometers with fresh water. This prevents inaccurate readings. Do NOT use storage battery hydrometers for any other purpose.

Corrections

The specific gravity of the electrolyte is affected by its temperature. The electrolyte expands and becomes less dense when heated. Its specific gravity reading is lowered. On the other hand, the electrolyte contracts and becomes denser when cooled. Its specific gravity reading is raised. In both cases, the electrolyte may be from the same fully charged storage cell. Thus, the effect of temperature is to distort the readings.

Most standard storage batteries use 80 °F as the normal temperature to which specific gravity readings are corrected. To correct the specific gravity reading of a storage battery, add 1 point for each 3 °F to the reading for each 3 °F above 80 °F. Subtract 1 point for each 3 °F below 80 °F. Figure 11-8 also shows a temperature correction chart for an 80 °F hydrometer.

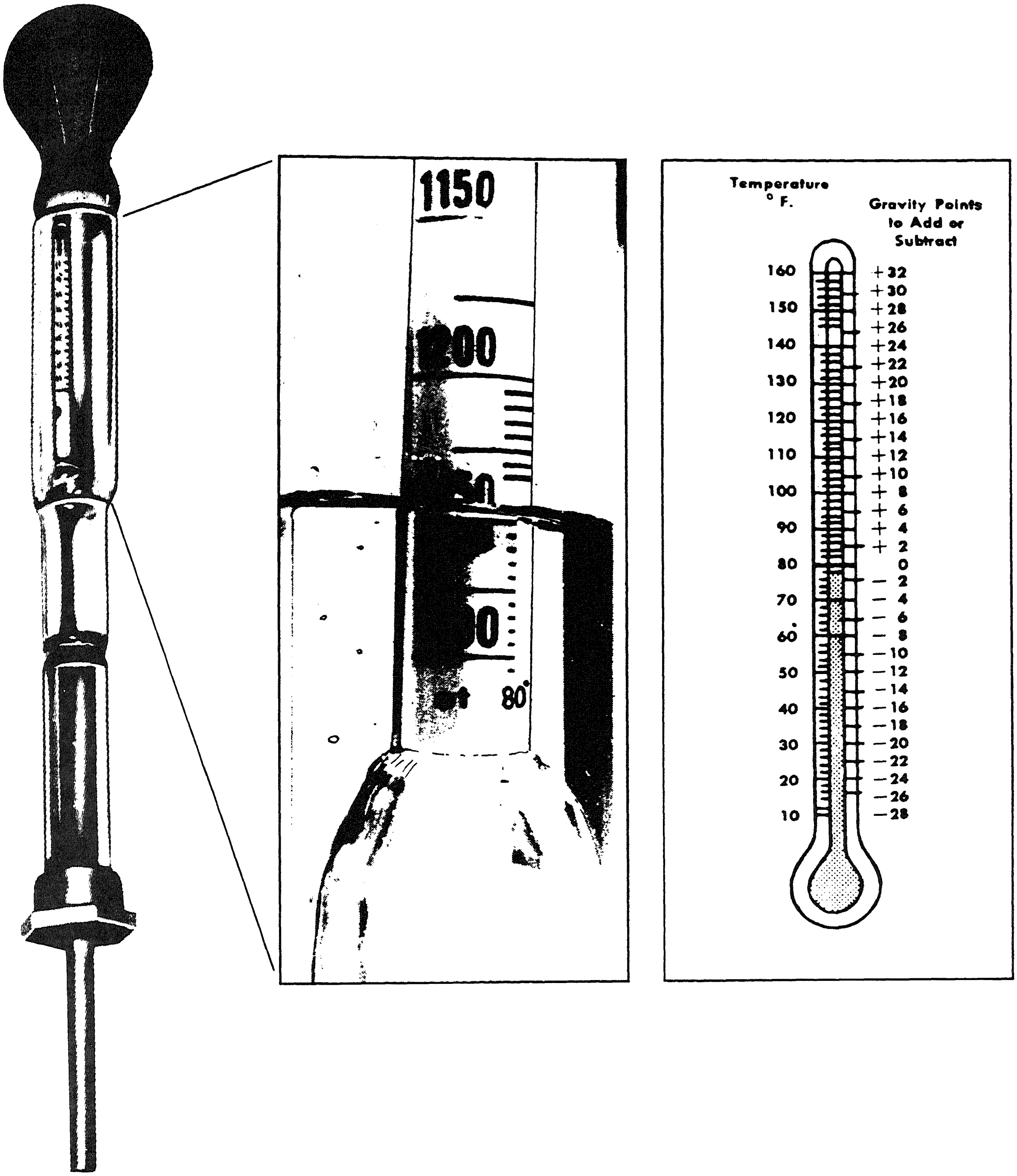
Adjusting Specific Gravity

Sometimes the specific gravity of a cell is more than it should be. You can reduce it to within limits by removing some of the electrolyte and adding distilled water. As stated earlier, charge the battery for 1 hour to mix the solution. Then take hydrometer readings. Continue the adjustment until you get the desired true readings.

NOTE: Only authorized personnel should add acid to a battery. Acid with a specific gravity above 1.350 is NEVER added to a battery.

MIXING ELECTROLYTE

The electrolyte of a fully charged battery usually has about 38-percent sulfuric acid by weight, or about 27 percent by volume. Distilled water and sulfuric acid are used to prepare the electrolyte. New batteries may be delivered with containers of concentrated sulfuric acid of 1.830 specific gravity or electrolyte of 1.400 specific



293.8

Figure 11-8.—Float-type 80 °F hydrometer with temperature conversion chart.

gravity. You must dilute both of these with distilled water to make electrolyte of the proper specific gravity. Use a container made of glass, earthenware, rubber, or lead for diluting the acid.

WARNING: When mixing electrolyte, ALWAYS POUR ACID INTO WATER—NEVER pour water into acid. Pour the acid slowly and cautiously to prevent excessive heating and splashing. Stir the solution continuously with a nonmetallic rod to mix the heavier acid with the lighter water. This will keep the acid from sinking to the bottom. When concentrated acid is diluted, the solution becomes very hot.

TREATMENT OF ACID BURNS

If acid or electrolyte from a lead-acid battery comes into contact with the skin, wash the affected area with large quantities of fresh water. Afterwards, apply a salve such as petrolatum, boric acid, or zinc ointment. If none of these salves are available, clean lubricating oil will suffice. When washing, use large amounts of water. A small amount of water might do more harm than good in spreading the acid burn. Treat any acid burn as soon as possible.

You can neutralize acid spilled on clothing with diluted ammonia or a solution of baking soda and water.

CAPACITY

The capacity of a battery is measured in ampere-hours (amp-hr). As mentioned before, the amp-hr capacity is equal to the product of the current in amperes and the time in hours during which the battery is supplying this current. The amp-hr capacity varies inversely with the discharge current. The size of a cell is determined generally by its amp-hr capacity. The capacity of a cell depends upon many factors. The most important of these are as follows.

1. The area of the plates in contact with the electrolyte
2. The quantity and specific gravity of the electrolyte
3. The type of separators
4. The general condition of the battery (degree of sulfating, plates buckled, separators warped, sediment in bottom of cells, and so forth)
5. The final limiting voltage

RATING

Storage batteries are rated according to their rate of discharge and amp-hr capacity. Most batteries are rated according to a 10-hour rate of discharge. That is, if a fully charged battery is completely discharged during a 10-hour period, it is discharged at the 10-hour rate. Thus, if a battery can deliver 20 amperes for 10 hours, the battery has a rating of 20 × 10, or 200 amp-hr. The 10-hour rating is equal to the average current that a battery can supply without interruption for 10 hours.

All standard batteries deliver 100 percent of their available capacity if discharged in 10 hours or more. But they will deliver less than their available capacity if discharged at a faster rate. The faster they discharge, the less amp-hr capacity they have.

The low-voltage limit is the maximum level that you can obtain useful energy from a battery. This limit is specified by the manufacturer. For example, at the end of a 10-hour discharge test on a battery, the closed-circuit voltmeter reading is about 1.75 volts per cell. The specific gravity of the electrolyte is about 1.060. At the end of a charge, its closed-circuit voltmeter reading, while the battery is being charged at the finishing rate, is between 2.4 and 2.6 volts per cell. The specific gravity of the electrolyte corrected to 80°F is between 1.210 and 1.220. In climates of 40°F and below, authority may be granted to increase the specific gravity to 1.280. Other batteries of higher normal specific gravity may also be increased.

TEST DISCHARGE

The test discharge is the best method of determining the capacity of a battery. Most battery switchboards are provided with equipment for giving test discharges. If proper equipment is not available, a tender, repair ship, or shore station may make the test. A battery is normally given a test discharge once every 6 months to determine the battery capacity. Test discharges are also given

when any cell of a battery after charge cannot be brought within 10 points of full charge. They are also given when one or more cells have less than normal voltage after an equalizing charge.

An equalizing charge always precedes a test discharge. After the equalizing charge, the battery is discharged at its 10-hour rate. This is done until (1) the total battery voltage drops to a value equal to 1.75 times the number of cells in series or (2) the voltage of any individual cell drops to 1.65 volts, whichever occurs first. Keep the rate of discharge constant throughout the test discharge. Because standard batteries are rated at the 10-hour capacity, the discharge rate for a 100 amp-hr battery is 100/10, or 10 amperes. If the temperature of the electrolyte at the beginning of the charge is not 80 °F, you must correct the time duration of the discharge for the actual temperature of the battery.

A battery of 100-percent capacity discharges at its 10-hour rate for 10 hours before reaching its low-voltage limit. If the battery or one of its cells reaches the low-voltage limit before the 10-hour period has elapsed, discontinue the discharge immediately. The percentage of capacity is determined from the equation

$$C = \frac{H_a}{H_t} \times 100$$

C = percentage of amp-hr capacity available

H_a = total hours of discharge

H_t = total hours for 100-percent capacity

Record the date for each test discharge on the storage battery record sheet.

For example, a 100 amp-hr, 6-volt battery delivers an average current of 10 amperes for 10 hours. At the end of this period, the battery voltage is 5.25 volts. On a later test the same battery delivers an average current of 10 amperes for only 7 hours. The discharge was stopped at the end of this time because the voltage of the middle cell was found to be only 1.65 volts. The percentage of capacity of the battery is now $\frac{7}{10} \times 100$, or 70 percent. Thus, the amp-hr capacity of this battery is reduced to $0.7 \times 100 = 70$ amp-hr.

STATE OF CHARGE

After a battery is discharged completely from full charge at the 10-hour rate, the specific gravity has dropped about 150 points to about 1.060. You can determine the number of points that the specific gravity drops per amp-hr for each type of battery. For each amp-hr taken out of a battery, a definite amount of acid is removed from the electrolyte and combined with plates.

For example: a battery is discharged from full charge to the low-voltage limit at the 10-hour rate. With a specific gravity drop of 150 points, 100 amp-hr are obtained. Then there is a drop of $\frac{150}{100}$, or 1.5 points per amp-hr delivered. If you know the reduction in specific gravity per amp-hr, you can predict the drop in specific gravity for this battery for any number of amp-hr delivered to a load. For example: 70 amp-hr are delivered by the battery at any rate or rates. Then the drop in specific gravity is 70×1.5, or 105 points.

Conversely, if you know the drop in specific gravity per amp-hr and the total drop in specific gravity, the amp-hr delivered by a battery can be found. For example: the specific gravity of the previously considered battery is 1.210 when the battery is fully charged and 1.150 when it is partly discharged. Then the drop in specific gravity is 1210 to 1150, or 60 points. The number of amp-hr taken out of the battery is $\frac{60}{1.5}$, or 40 amp-hr. Thus, you can find the number of amp-hr expended in any battery discharge from the following items.

1. The specific gravity when the battery is fully charged
2. The specific gravity after the battery has been discharged
3. The reduction in specific gravity per amp-hr

Voltage alone is not a reliable indication of the state of charge of a battery. It is reliable when the voltage is near the low-voltage limit on discharge. During discharge the voltage falls. The higher the rate of discharge the lower will be the terminal voltage. Open-circuit voltage is of little value. This is because the variation between full

charge and complete discharge is so small. It is only about 0.1 volt per cell. However, abnormally low voltage does indicate injurious sulfation or some other serious deterioration of the plates.

TYPES OF CHARGES

You can give the following types of charges to a storage battery, depending upon the condition of the battery.

- Initial charge
- Normal charge
- Equalizing charge
- Floating charge
- Emergency charge

Initial Charge

When a battery is shipped dry, the plates are in an uncharged condition. After the electrolyte has been added, convert the plates into the charged condition. Do this by giving the battery a long low-rate initial charge. To charge the battery, follow the manufacturer's instructions. These are shipped with each battery. If the manufacturer's instructions are not available, refer to instructions in current directives.

Normal Charge

A normal charge is a routine charge. You should give it following the nameplate data during the ordinary cycle of operation. It restores the battery to its charged condition. Observe the following steps.

1. Determine the starting and finishing rate from the nameplate data.
2. Add water, as necessary, to each cell.
3. Connect the battery to the charging panel. Make sure the connections are clean and tight.
4. Turn on the charging circuit. Set the current through the battery at the value given as the starting rate.
5. Check the temperature and specific gravity of pilot cells hourly.
6. When the battery begins to gas freely, reduce the charging current to the finishing rate.

A normal charge is complete when the specific gravity of the pilot cell, corrected for temperature, is within 5 points (0.005) of the specific gravity obtained on the previous equalizing charge.

Equalizing Charge

An equalizing charge is an extended normal charge at the finishing rate. Give it periodically. It ensures all the sulfate is driven from the plates and all the cells are restored to a maximum specific gravity. Continue the equalizing charge until the specific gravity of all cells, corrected for temperature, shows no change for a 4-hour period. Take readings of all cells every half hour.

Floating Charge

You may maintain a battery at full charge by connecting it across a charging source that has a voltage maintained within the limits of from 2.13 to 2.17 volts per cell of the battery. In a floating charge, you determine the charging rate by the battery voltage rather than by a definite current value. Maintain the voltage between 2.13 and 2.17 volts per cell with an average as close to 2.15 volts as possible.

Emergency Charge

Use an emergency charge when a battery must be recharged in the shortest possible time. Start the charge at a much higher rate than is normally used for charging. Use it only in an emergency. This type of charge may be harmful to the battery.

CHARGING RATE

Normally, the charging rate of Navy storage batteries is given on the battery nameplate. If the available charging equipment does not have the desired charging rates, use the nearest available rates. However, do not let the rate become so high that violent gassing occurs. NEVER ALLOW THE TEMPERATURE OF THE ELECTROLYTE IN ANY CELL TO RISE ABOVE 125 °F (52 °C).

CHARGING TIME

Continue the charge until the battery is fully charged. Take frequent readings of specific gravity during the charge. Correct these readings to 80 °F. Then compare them with the reading taken before the battery was placed on charge. If you know the rise in specific gravity in points per amp-hr, the approximate time in hours required to complete the charge is as follows:

$$\frac{\text{rise in specific gravity in points to complete charge}}{\text{rise in specific gravity in points per amp-hr} \times \text{charging rate in amp}}$$

GASSING

When you are charging a battery, a portion of the energy is dissipated in the electrolysis of the water in the electrolyte. Thus, hydrogen is released at the negative plates. Oxygen is released at the positive plates. These gases bubble up through the electrolyte. They collect in the air space at the top of the cell. If violent gassing occurs when the battery is first placed on charge, the charging rate is too high. If the rate is not too high, steady gassing from the charging shows that the battery is almost fully charged.

> CAUTION
>
> A mixture of hydrogen and air can be dangerously explosive. DO NOT permit smoking, electric sparks, or open flames near charging batteries.

SUMMARY

In this chapter we have discussed the uses and operation of the UPS systems found on gas turbine ships. Since these systems are very important to the ship when recovering from a loss of power casualty, they must be kept in a very high state of readiness. You perform preventive maintenance carefully to ensure the system is kept up to designed standards. Strictly follow safety precautions found in technical manuals and on maintenance requirement cards (MRCs). Carefully follow all posted safety precautions. You should perform corrective maintenance on the UPS systems promptly. Failure to have the UPS system in top working order could jeopardize the entire mission of a ship.

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CHAPTER 12

MOTORS, GENERATORS, CONTROLLERS, AND SWITCHBOARDS (60 HERTZ)

Many of the tasks assigned to GSEs involve the repair, troubleshooting, and operation of components of the 60-Hz power distribution system. This may involve work on lighting systems, power panels, motor controllers, motors, receptacle circuits, and distribution switchboards. Most of the 60-Hz electrical equipment GSEs work with is found in the MERs and generator rooms. Gas turbine ships also have Electrician's Mates assigned. They are normally responsible for the electrical equipment found outside the main machinery spaces.

Equipment maintenance involves replacement of motor bearings, repair of motor controllers, resetting CBs, and replacement of fuses. Maintenance also includes other tasks involving 60-Hz equipment. Usually, GSEs do not become involved with motor rewind. For more information on this subject, consult *Electrician's Mate 3 & 2*, NAVEDTRA 10546-E.

The information in this chapter provides you with basic knowledge of the equipment, procedures, terminology, and special precautions used with 60-Hz equipment. After reading this chapter and completing the corresponding NRCC, you should be able to identify 60-Hz equipment. You should also be able to discuss the operation of various types of motor control circuits. You should be able to describe the numbering system used to identify electrical equipment and cables. In this chapter, we briefly discuss generators. This topic was covered in chapter 8. A major area covered in this chapter will familiarize you with the procedures used to parallel generators from the switchboard and the EPCC.

The material presented in this chapter is representative in nature. It is used to explain principles of operation. By studying this material, you should be able to relate to the specific equipment found on your ship.

PRINCIPLES OF ELECTRICITY

Electricity is one of the primary means of distributing energy aboard ships. Any piece of equipment that requires energy to do work must have a source of energy to draw from. Energy is stored in several forms. As proved by Einstein in the 1930s, it is never destroyed but only converted in form. An example is the energy needed to heat CRP oil on the DD-963 class ship. This oil is heated by electric heaters. The energy used by this heater is in the form of electrical current. This current is changed to heat to warm the oil. But, no energy is lost; it has just changed state. The electric power was generated by moving a conductor through a magnetic field. This has changed rotating energy into electricity with no loss of energy. (NOTE: This holds true for ideal conditions. Some energy will be converted into heat because of bearing friction, line losses, and so on. The energy is still not lost, though, only converted to several types of energy.) Energy is required to make the rotating energy. In our case, heat, in the form of hot gas, causes a turbine to rotate and drives the generator. The heat is generated in the turbine combustor by burning fossil fuel. Fossil fuel is another type of energy made from some other source. The cycle goes on and on because energy is never lost.

Electricity is one of the easiest methods of distributing energy. Distributing hot gases would require massive insulated ducting and heat exchangers. Distributing rotating energy would require many complex gearboxes and shafts. All

these systems would make control of this energy very difficult.

The use of electricity for our primary distribution of energy is the most efficient form of energy for our purposes. We can use small control components, minimize losses because of heat dissipation, and avoid large complex components for power transfer. Imagine the problems that could occur if every pump in an engine room had an independent GT for power. Most electricity used for transfer of power is 60-Hz a.c. power. D.c. is frequently used as control power for these a.c. circuits, as well as control of the GTs. The Navy Electricity and Electronics Training Series (NEETS) Module 1 (NAVEDTRA 172-01-00-79) and Module 2 (NAVEDTRA 172-02-00-79) discuss principles of matter, energy, direct current, and alternating current. These courses are recommended. They will help you understand the electrical principles needed when discussing electric power.

A.C. AND D.C. VOLTAGES

Both a.c. and d.c. voltages are used on gas turbine ships. These voltages were explained in the NEETS modules. If you are not familiar with the different properties of these voltages, you should complete the NEETS Modules 1 and 2 before continuing this chapter. On gas turbine ships, a.c. voltages are used for SS power. D.c. voltages are used primarily for control voltages in electronic components. D.c. is also used for a backup source of power in UPS systems.

A.c. voltages have many properties that make them preferable over d.c. for SS use. D.c. motors and controllers are larger and more expensive. They are more complex and require more maintenance than a.c. systems providing the same functions. A primary reason a.c. is used is it can be stepped down for lower voltage applications without a loss of power. When lower voltage in a d.c. circuit is used, a series resistor must be used to dissipate the excess voltage. This resistor uses power and creates heat to lower the voltage to a usable level. In a.c. circuits, a transformer can step down the voltage with very little loss of power.

A.c. voltages are not used in control logic applications because they constantly change amplitude. Logic circuits require constant voltages to determine ON/OFF status to logic gates. Therefore, a.c. could NEVER be used for this purpose. A.c. can be used in control circuits, such as motor controllers, because they are usually not solid state. A.c. motor controls use relays and switches for control. A.c. is well suited for this purpose.

RESISTANCE

As discussed in NEETS Module 1, resistance is the property of a material to resist current flow. When current flows through a conductor or wire, its size, composition, length, and temperature affect the amount of power lost because of the resistance of the conductor. All materials and all electrical components have some degree of resistance. This degree varies greatly because of the properties of the materials. Design engineers use these known properties to design electrical components. Copper is used in electrical wires because of its low cost and low resistance. There are better conductors than copper, but they cost significantly more. Rubber and plastic have a high resistance to current flow. They are used as insulators. Again, there are better insulators, such as glass, but they are impractical for use as shielding on cables.

Knowing the resistance value of a component allows designers to know the amount of power used by a component. A 60-watt light bulb has a higher resistance than a 150-watt bulb used at the same voltage.

Resistance is commonly used as a measurement to determine the condition of electrical circuits. A very high or infinite resistance reading of a relay coil or a motor indicates an open exists in the circuit. This measurement is taken using an ohmmeter or megger. (NEETS Module 16, NAVEDTRA 172-16-00-84, details the use of this test equipment.) A very low or zero resistance value read on the coil or motor indicates a short circuit. Resistance values are commonly read to determine the condition of insulation on electrical components. These measurements are almost always taken with a megger. A low resistance (usually below 1 million ohms [1MΩ]) may indicate a breakdown in the insulation on a motor or cable. A breakdown of insulation could cause a condition known as a ground. This condition exists when some of the voltage in a circuit is

allowed to go to the ship's hull. A ground on two phases of a circuit through the hull is a short circuit. Short circuits are dangerous conditions. They could result in shock hazards as well as electrical fires. Therefore, you must quickly isolate and repair grounds to prevent damage.

Resistance is used in electronic circuits to enable many circuits to function. Resistors of known values are used to allow transistors to operate. There are many types of resistors used in these circuits. They are detailed in NEETS Module 1.

CONTINUITY

Checking circuit continuity ensures no opens exist in the wiring of a device or cable. Continuity is commonly measured with an ohmmeter. Normally, when checking continuity of a circuit, you are not very interested in the exact resistance. But, you are interested in either a very high or infinite reading or a very low reading. Never perform continuity checks with an ohmmeter on live circuits. First secure power and obtain a circuit diagram. Then simply go from point to point in the circuit determining any open points. If you get a very high or infinite reading, this shows an open or loss of continuity. Continuity checks are very useful when troubleshooting motor controllers. Use them to find open contacts, coils, or fuses.

MOTORS

GSEs are called upon to troubleshoot or repair 60-Hz a.c. motors. The size of these motors varies. They are as large as lube oil pump motors or as small as cooling fan motors in electronic enclosures. Whatever their size, motors are all similar in theory of operation and construction. Motor repairs are usually restricted to bearing replacement. Other repairs, such as winding repairs, are done by rewinding. Motor rewind is normally done by an intermediate maintenance activity (IMA) such as a SIMA or a Navy tender. It may also be done at shipyards.

The two major types of motor you may encounter are the polyphase (3-phase) and the single-phase. Most of the large motors found on gas turbine ships are polyphase. Smaller motors, like those used for electronic enclosure cooling fans, are normally single-phase.

POLYPHASE MOTORS

Polyphase, or 3-phase, motors are the most common large motors on ships. You will probably operate and repair this type more often than the small single-phase motors.

Polyphase Induction Motor Theory

To better understand the operating principles of polyphase induction motors, we will discuss the a.c. theory. Figure 12-1 shows how a rotating field is produced by stationary coils, or windings, when they are supplied by a 3-phase power source. For purposes of explanation, rotation of the field is developed in figure 12-1 by stopping it at six selected instants. These instants are marked off at 60-degree intervals on the sine waves. They represent currents in the three phases A, B, and C.

At instant (1) the current in phase B is maximum positive (assume plus 10 amperes in this example). Current is considered to be positive when it is flowing out from a motor terminal. Also, at instant (1) current flows into the A and C terminals at half value (minus 5 amperes each in this case). These currents combine at the neutral (common connection) to supply plus 10 amperes out through the B phase.

The resulting field at instant (1) is set downward and to the right (see arrow NS). The major portion of this field is produced by phase B (full strength). It is aided by the adjacent phases A and C (half strength). The weaker portions of the field are indicated by the letters *n* and *s*. The field is two-pole extending across the space that would normally contain the rotor.

At instant (2) the current in phase B is reduced to half value (plus 5 amperes). The current in phase C has reversed its flow from minus 5 amperes to plus 5 amperes. The current in phase A has increased from minus 5 to minus 10 amperes.

The resulting field at instant (2) is now set upward and to the right (see arrow NS). The major portion of the field is produced by phase A (full strength), and the weaker portions are produced by phases B and C (half strength).

At instant (3) the current in phase C is plus 10 amperes and the field extends vertically upward. At instant (4) the current in phase B becomes minus 10 amperes; the field extends upward and to the left. At instant (5) the current in phase A becomes plus 10 amperes. The field

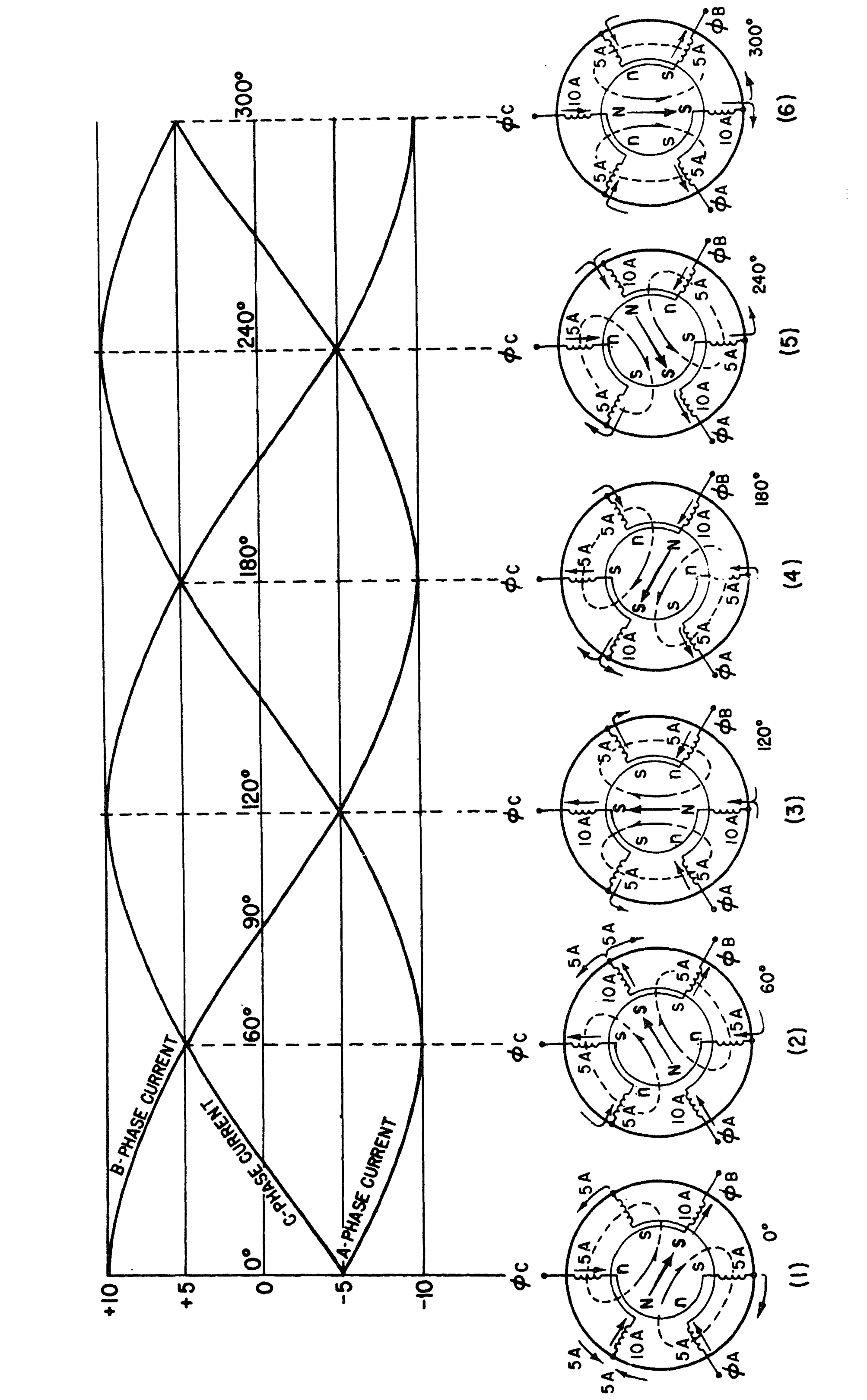

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Figure 12-1.—Development of a rotating field.

extends downward and to the left. At instant (6) the current in phase C is minus 10 amperes; the field extends vertically downward. Instant (7) (not shown) corresponds to instant (1) when the field again extends downward and to the right.

Thus, a full rotation of the two-pole field has been accomplished through one full cycle of 360 electrical degrees of the 3-phase currents flowing in the windings.

Polyphase Motor Construction

The driving torque of a.c. motors comes from the reaction of current-carrying conductors in a magnetic field. In induction motors (figure 12-2)

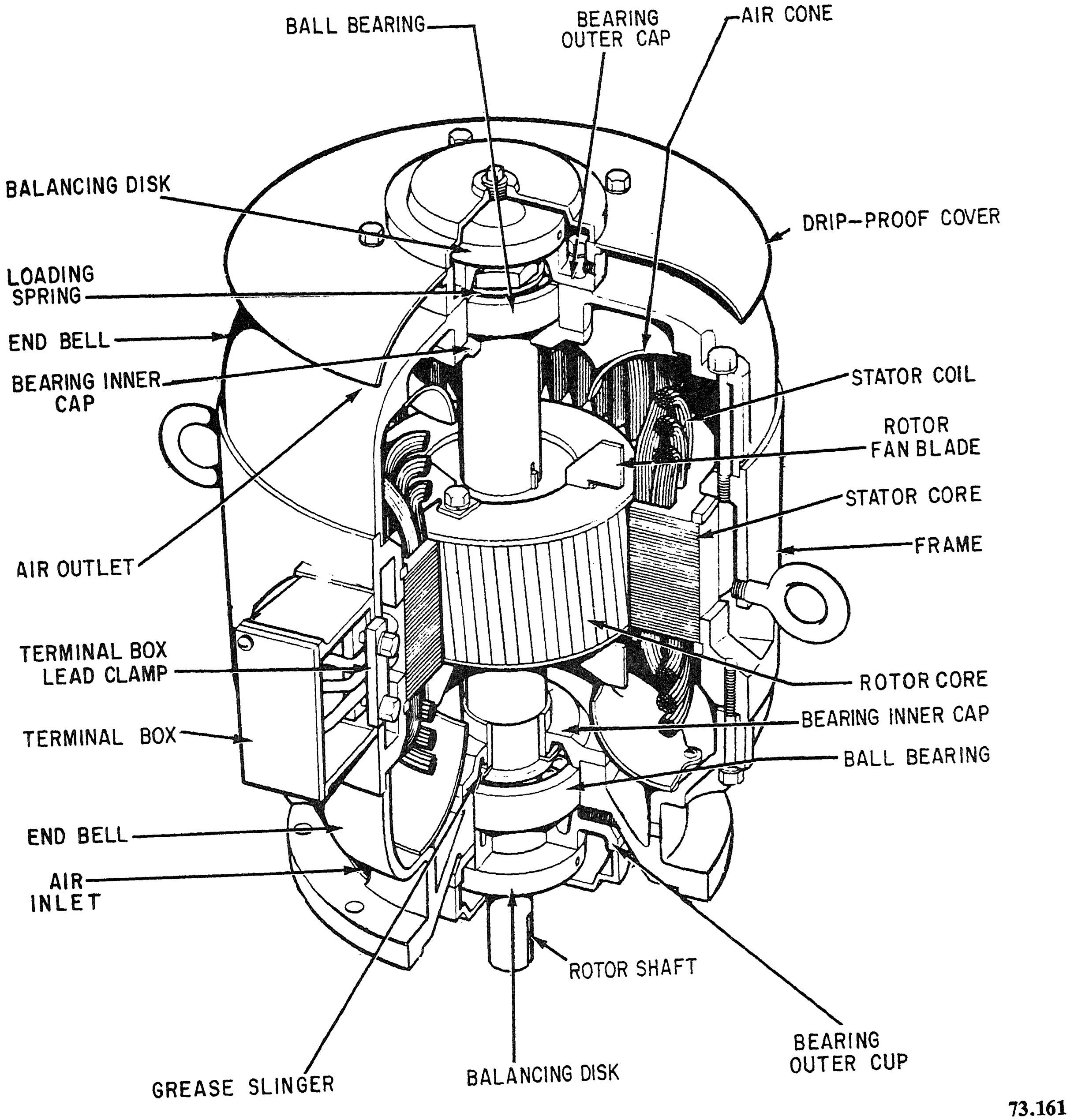
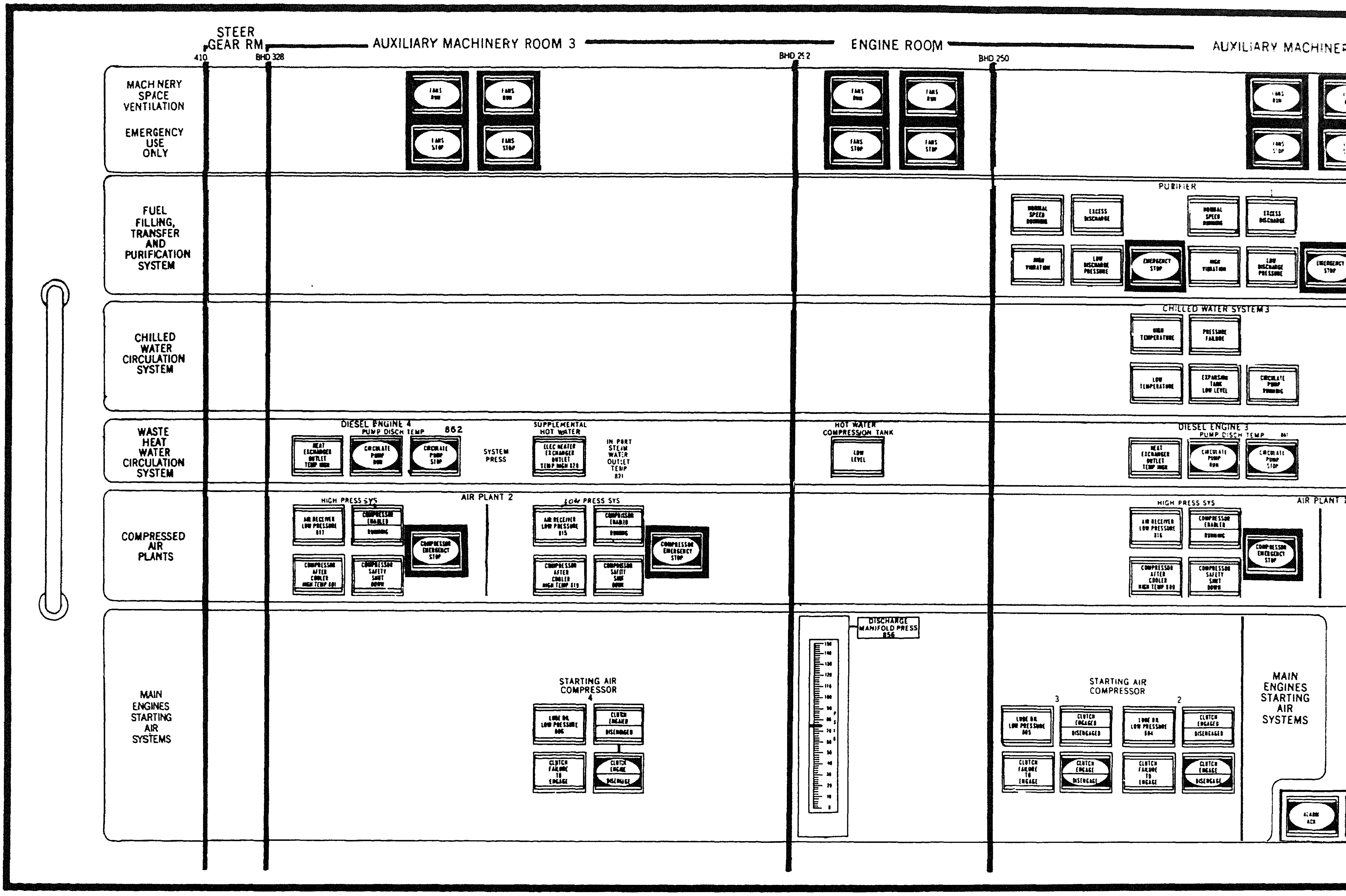


Figure 12-2.—Typical 3-phase induction motor.



STEER GEAR RM
410
BHD 328
AUXILIARY MACHINERY ROOM 3
BHD 292
ENGINE ROOM
BHD 250
AUXILIARY MACHINER
MACHINERY SPACE VENTILATION
EMERGENCY USE ONLY
FUEL FILLING, TRANSFER AND PURIFICATION SYSTEM
PURIFIER
CHILLED WATER CIRCULATION SYSTEM
CHILLED WATER SYSTEM 3
WASTE HEAT WATER CIRCULATION SYSTEM
DIESEL ENGINE 4
PUMP DISCH TEMP
862
SYSTEM PRESS
SUPPLEMENTAL HOT WATER
IN PORT STEAM WATER OUTLET TEMP 871
HOT WATER COMPRESSION TANK
DIESEL ENGINE 3
PUMP DISCH TEMP
COMPRESSED AIR PLANTS
HIGH PRESS SYS
AIR PLANT 2
LOW PRESS SYS
AIR PLANT
MAIN ENGINES STARTING AIR SYSTEMS
DISCHARGE MANIFOLD PRESS 856
STARTING AIR COMPRESSOR
4
3
2
MAIN ENGINES STARTING AIR SYSTEMS

A4

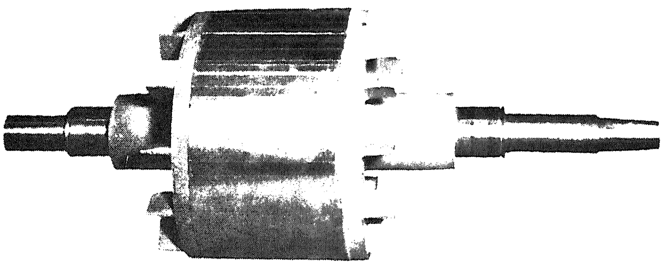
A3

the rotor currents are supplied by electromagnetic induction. The stator windings (coils) receive the 3-phase power from terminals in the terminal box. They produce the previously mentioned rotating magnetic field. The magnetic field rotates continuously at constant speed (synchronous) regardless of the load on the motor. The rotor is not connected electrically to the power supply. The induction motor gets its name from the fact that electromagnetic induction takes place between the stator and the rotor under operating conditions. The magnetic revolving field produced by the stator cuts across the rotor conductors. This induces a voltage in the conductors. The induced voltage causes rotor current to flow. Hence, motor torque is developed by the interaction of the rotor's magnetic field and the stator's revolving magnetic field. Figure 12-3 shows the rotor and stator of a typical polyphase (3-phase) induction motor.

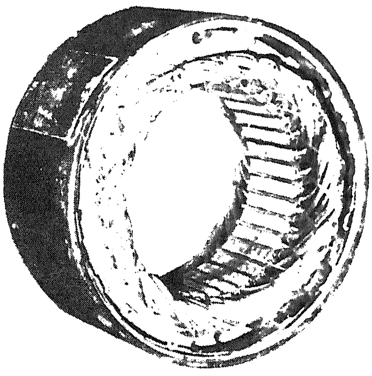
Many other components of the 3-phase motor are used for cooling, support, balancing, and protection of the motor. Ball bearings support the rotor and provide for low friction loss. (Bearings will be discussed later in this chapter.) Balancing disks balance the rotor. Rotor fans are normally provided to cool the motor with air from the air inlets in the end bells. Vertically mounted motors usually have a drip-proof cover over the top to prevent moisture from entering the housing.

SINGLE-PHASE MOTORS

Single-phase motors operate on a single-phase power supply. These motors are used extensively in fractional horsepower sizes in commercial and domestic applications. The advantages of using single-phase motors in small sizes are that they are less expensive to manufacture than other types, and they eliminate the need for 3-phase a.c. lines. Single-phase motors are used in electronic



A. ROTOR



B. STATOR

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Figure 12-3.—Rotor and stator of a typical polyphase induction motor.

equipment, fans, refrigerators, portable drills, grinders, and so forth.

A single-phase induction motor with only one stator winding and a cage rotor is like the 3-phase induction motor with a cage rotor. The single-phase motor, though, has no revolving magnetic field at start, hence, no starting torque. However, the rotor can be brought up to speed by special design of the stator winding. Then the induced currents in the rotor will cooperate with the stator currents to produce a revolving field. This causes the rotor to continue to run in the start direction.

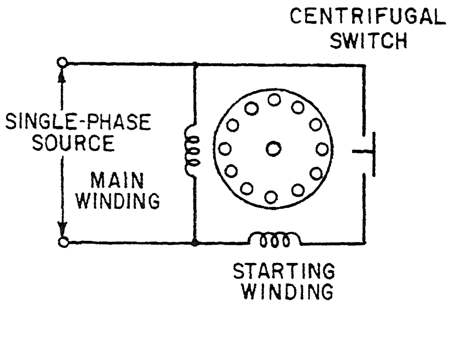
Several methods provide the single-phase motor with starting torque. These methods identify the motor as split-phase, capacitor, or universal.

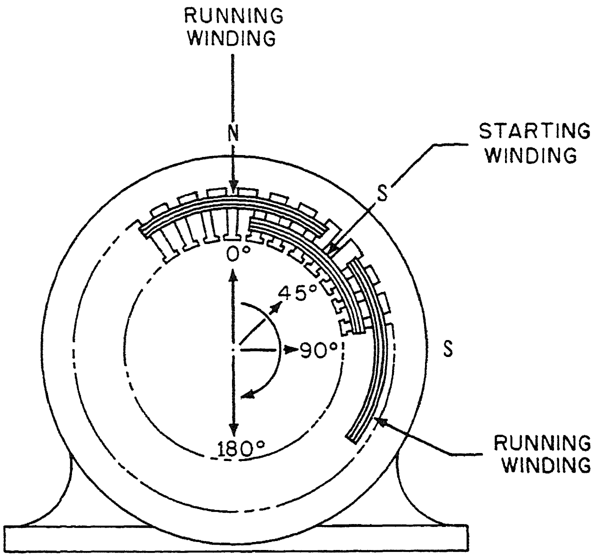
Split-Phase Motor

The split-phase motor (figure 12-4) has a stator composed of slotted laminations. The stator has an auxiliary (starting) winding and a running (main) winding (figure 12-4, item A). The axes of these two windings are displaced by an angle of 90 electrical degrees. The starting winding has fewer turns and smaller wire than the running winding; hence, the starting winding has higher resistance and less reactance. The main winding occupies the lower half of the slots. The starting winding occupies the upper half (figure 12-4, item B). The two windings are connected in parallel across the single-phase line that supplies the motor. The motor gets its name from the action of the stator during the starting period.

At start, these two windings produce a magnetic revolving field. This rotating field rotates around the stator air gap at synchronous speed. As it moves around the air gap, it cuts across the rotor conductors and induces a voltage in them. This voltage is maximum in the area of highest field intensity. Therefore, it is in phase with the stator field. The rotor current lags the rotor voltage at start by an angle that approaches 90 degrees because of the high rotor reactance. The interaction of the rotor currents and the stator field causes the rotor to accelerate in the direction in which the stator field is rotating. During acceleration the rotor voltage, current, and reactance are reduced. The rotor currents come closer to an inphase relation with the stator field.

When the rotor reaches about 75 percent of synchronous speed, a centrifugally operated switch (figure 12-4, item C) disconnects the





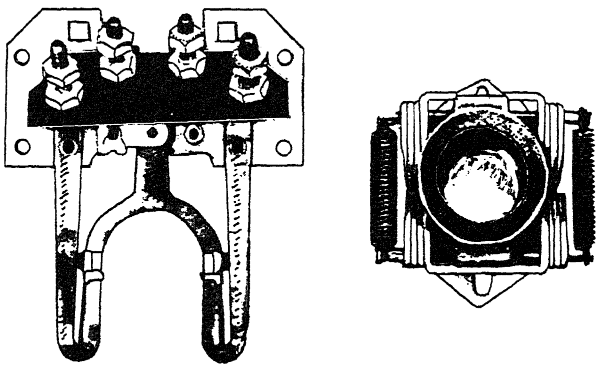


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Figure 12-4.—Split-phase motor: (A) circuit diagram, (B) winding configuration, and (C) centrifugal switch.

starting winding from the line supply. The motor continues to run on the main winding alone. Then the rotating field is maintained by the interaction of the rotor and stator magnetomotive forces.

Usually it is the starting winding that burns out in single-phase motors. The centrifugal switch cuts the starting winding out of the system when the motor reaches about 75 percent of full speed. When the motor is overloaded, the speed decreases and allows the centrifugal switch to energize the starting windings. Then the motor speeds up enough so the centrifugal switch opens the starting circuit again. This constant opening and closing of the starting winding circuit will cause failure of the winding. This may also apply to capacitor motors using centrifugal switches.

Capacitor Motor

The capacitor motor is single-phase and has a capacitor in series with the starting winding. An external view is shown in figure 12-5 with the capacitor located on top of the motor. The capacitor produces a greater phase displacement of currents in the starting and running windings than is produced in the split-phase motor. The starting winding in the capacitor motor has many more turns of larger wire than the split-phase motor. The starting winding is connected in series with the capacitor. The starting winding current is displaced about 90 degrees from the running winding current. The axes of the two windings are also displaced by an angle of 90 degrees. Therefore, a higher starting torque is produced than that in the split-phase motor. The starting torque of the capacitor motor may be as much as 350 percent of the full-load torque.

If the starting winding is cut out after the motor has increased in speed, the motor is called a CAPACITOR-START MOTOR. If the starting winding and capacitor are designed to be left continuously in the circuit, the motor is called a CAPACITOR-RUN MOTOR. Electrolytic capacitors for capacitor-start motors vary from about 80 μf for 1/8-hp motors to 400 μf for 1-hp motors. Capacitor motors of both types are made from small fractional hp motors up to about 10 hp. They drive grinders, drill presses, and refrigerator compressors. They are used to drive other loads that require relatively high starting torque. The direction of rotation of the capacitor motor may be reversed. This is done by interchanging the starting and winding leads. Rotation of a split-phase motor may be also be reversed in this manner provided both leads of the start winding are accessible.

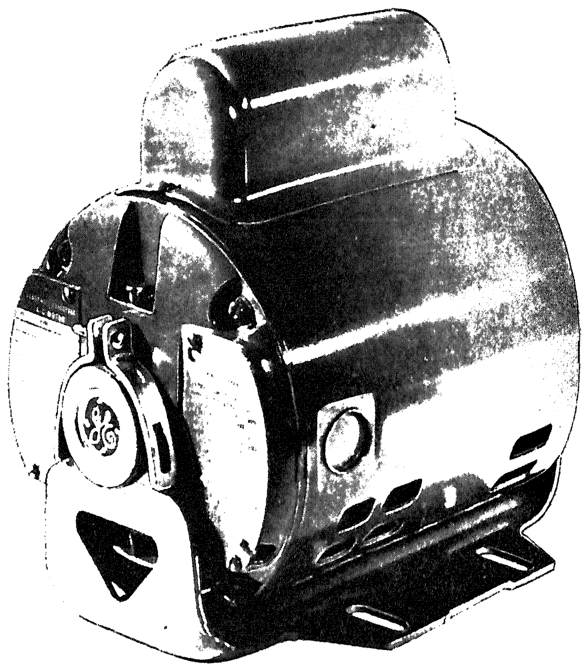

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Figure 12-5.—Capacitor motor.

Universal Motor

A universal motor can be operated on either d.c. or single-phase a.c. Aboard Navy ships, they are used extensively for portable tools. The motor is constructed with a main field connected in series with an armature. The armature is similar in construction to any d.c. motor. When electric power is applied, the magnetic force created by the fields reacts with the magnetic field in the armature to cause rotation.

A.C. GENERATORS

There are two types of a.c. generators, but only one type is used on gas turbine ships. The two types are

- rotating armature—stationary field, and
- rotating field—stationary armature.

The type we will discuss is the rotating field—stationary armature. It is used on all gas turbine ships. The size of the generators found on gas turbine ships varies. The 1000 kW diesel-driven generator is used on the FFG-7 class. The 2500 kW GTG is used on the CG-47 class. In this section, we will discuss only generator construction. Chapter 8 covered the GTGS. Usually, GSEs are not assigned to work with the diesels found on the FFG-7s.

The two major components of the rotating field—stationary armature are the stator and the rotor (figure 12-6). The stator is the stationary part of the generator enclosed in the generator

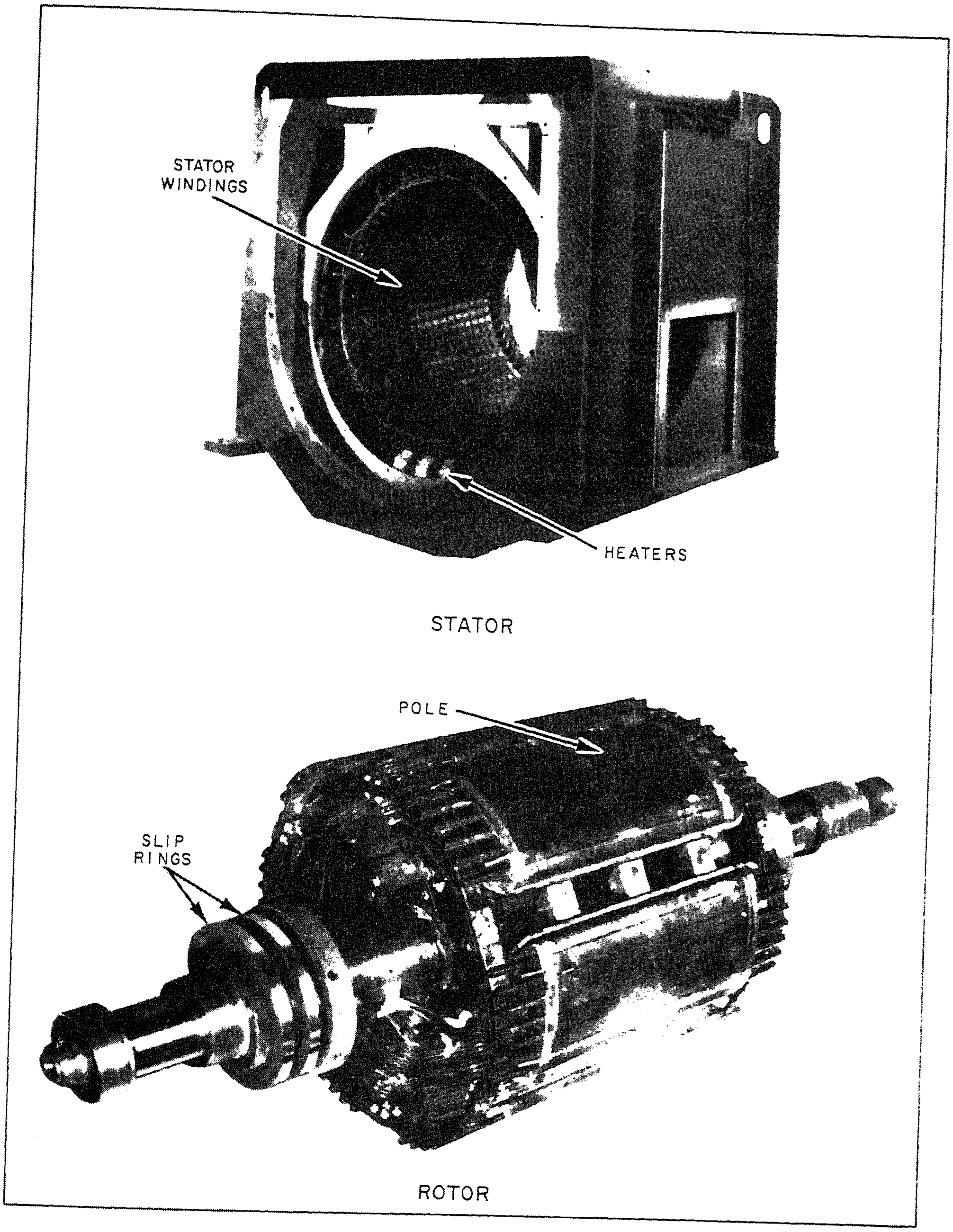

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Figure 12-6.—A.c. generator stator and rotor.

housing. It is also known as the armature. The stationary armature is the set of windings into which voltage is induced. It supplies power to the ship's loads (via a switchboard). The rotor is the rotating part of the generator. It is driven by the prime mover, either a diesel engine or GT. D.c. is induced into the rotor by the voltage regulator circuit to create the rotating magnetic field. The number of magnetic poles needed in the rotor is determined by the speed of the generator and the frequency needed at the output. NEETS Module 5 (NAVEDTRA 172-05-00-79) details the theory of a.c. generators. Familiarizing yourself with NEETS Module 5 will aid you in understanding this section.

Generators on gas turbine ships rotate at 1800 rpm. The rotors of these generators are the salient pole type and have four magnetic poles, two positive and two negative. Field excitation is provided by either slip rings and brushes or a brushless exciter. The slip rings or exciter allows a path of flow for the current from the voltage regulator to the rotor. Varying the amount of current to the rotor allows you to control the generator output voltage and the reactive (amperage) load balance.

Generator frequency is controlled by prime mover speed. So is resistive load balance (load balance of the kW load). Speed of the prime mover is regulated by the engine governor system. By adjusting the governor setting on two generators in parallel, an operator can equalize the resistive load and keep frequency at 60 Hz.

For more information on voltage and frequency regulation, refer back to chapter 8 of this RTM, Allison 501-K17 Gas Turbine Engine.

GENERATOR AND MOTOR MAINTENANCE

At the shipboard level, maintenance on generators and motors is usually limited to trouble isolation, bearing repair, and cleaning. Maintenance actions on motors and generators are similar. As stated above, major repairs, such as rewinding and balancing, are done at IMAs or shipyards.

CLEANING MOTORS AND GENERATORS

One of your most important jobs is to keep all electrical machinery clean. Dust, dirt, and foreign matter (such as carbon, copper, or mica) tend to block ventilation ducts. This increases resistance to the dissipation of heat. It causes local or general overheating. If the particles are conducting or form a conducting paste through the absorption of moisture or oil, the winding may become short circuited or grounded. Also, abrasive particles may puncture insulation. Iron dust is very harmful since the dust is agitated by magnetic pulsations. Proper cleaning of motors and generators involves the use of wiping rags, suction, LP air, and solvents.

Wiping with a clean, lint-free, dry rag removes loose dust or foreign particles from accessible parts. Cheesecloth makes an effective cleaning rag. When wiping, do not neglect the end windings, slip ring insulation, connecting leads, and terminals.

Suction is preferred to compressed air for removing abrasive dust and particles from inaccessible parts. This is because it lessens the possibility of damage to insulation. A vacuum cleaner is good for this purpose. If one is not available, a flexible tube attached to the suction side of a portable blower makes a usable vacuum cleaner. Always exhaust the blower to a suitable sump or overboard. When possible, remove grit, iron dust, and copper particles only by suction methods.

Clean, dry, compressed air is good to remove dry, loose dust and foreign particles. This is particularly true of inaccessible locations, such as air vents in the armature punchings. Use air pressure up to 30 psi to blow out motors or generators of 50 hp or 50 kW or less; use pressure up to 75 psi to blow out higher rated machines. Where air lines carry higher pressure than is suitable, use a throttling valve to reduce the pressure. Always blow out any accumulation of water in the air pipe or hose before air blasting the machine. Be very careful with compressed air if abrasive particles are present. These particles may be driven into the insulation and puncture it or be forced beneath insulating tapes. Use compressed air only after the machine has been opened on both ends. This allows the air and

dust to escape. Compressed air is no good if the dust is not suitably removed from the machine. The best method is to attach a suction blower to an opening in the opposite end from the air jet to remove the dirt-ladened air.

Avoid using solvents for cleaning electrical equipment whenever possible. However, their use is necessary for removing grease and pasty substances having oil and carbon or dirt. Alcohol harms most types of insulating varnishes. Do not use it for cleaning electrical equipment. Never use solvents with gasoline or benzine for cleaning purposes. Do not use carbon tetrachloride because of its extremely high toxicity. Always refer to *Naval Ships' Technical Manual* (NSTM), Chapter 300, for approved solvents.

Use fresh water to flush out motors, generators, and other electrical equipment that are wet with salt water. Then dry the equipment. Never let the equipment dry before flushing with fresh water. For complete information on washing and drying procedures, refer to *Naval Ships' Technical Manual*, Chapter 300.

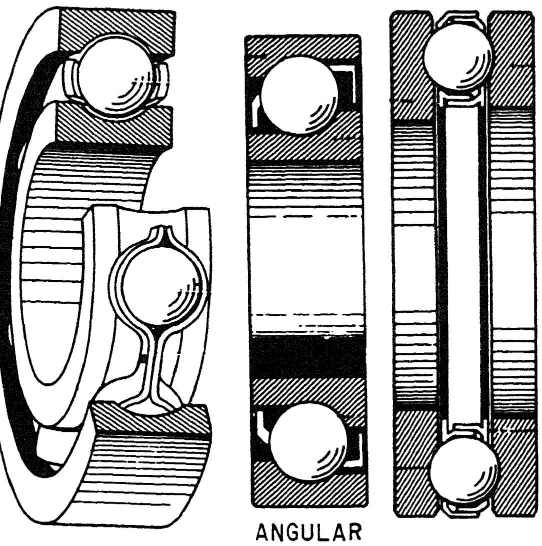

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Figure 12-7.—Representative types of ball bearings.

BEARINGS

When a shaft is mounted during rotation, friction develops between the contact point of the shaft and the mount. Friction develops heat. Thus, the friction produced in a shaft housing must be reduced to a minimum. This is done to obtain satisfactory performance and longer life of the shaft. Bearings reduce the amount of friction produced by shafts in their housings.

The two common types of bearings found in motors and generators are antifriction bearings and friction bearings.

Antifriction Bearings

Rolling antifriction bearings are of two types: ball and roller bearings. Basically, all rolling bearings have two hardened steel rings, hardened steel rollers or balls, and separators. The annular, ring-shaped ball bearing is most commonly used in electric motors and generators used by the Navy. This bearing is further divided into three types, classified by the load it bears—(1) radial, (2) angular contact, and (3) thrust. Examples of these three bearings are shown in figure 12-7.

The rotating element of an electric motor or generator subjects a ball bearing to a combination of loads—radial, thrust, and angular. Radial loads result from forces applied to the bearing perpendicular to the shaft. Thrust loads result from forces applied to the bearing parallel to the shaft. Angular loads result from a combination of radial and thrust loads. Bearing loads in electric motors and generators are mostly due to the weight of the rotating element. The method of mounting the unit is a major factor in deciding the type of bearing used in its construction. In a vertically mounted unit, the thrust bearing would be used; the radial bearing is common to most horizontal units.

WEAR.—Usually you do not have to measure the air gap on machines with ball bearings. This is because the construction ensures proper bearing alignment. Moreover, ball bearing wear great enough to be detected by air gap measurements would cause improper operation.

To determine the extent of wear in these bearings, periodically feel the bearing housing while the machine is running. This detects any signs of overheating or excessive vibration. Also,

listen to the bearing for the presence of unusual noise.

Rapid heating of a bearing indicates danger. Bearing temperature may feel uncomfortable to the hand and might be a sign of dangerous overheating. This is not always so. The bearing may be all right if it has taken an hour or more to reach that temperature. You can expect serious trouble if that same temperature is reached within the first 10 or 15 minutes of operation.

The test for excessive vibration relies a lot on the experience of the tester. You should know the normal vibration of the machine to correctly detect, identify, and interpret any unusual vibrations. Vibration, like heat and sound, is easily telegraphed. A thorough search is generally required to locate its source and to determine its cause.

Ball bearings are inherently more noisy in normal operation than sleeve bearings (discussed later). Remember this when testing for the presence of abnormal noise in the bearing. A good method for sound testing is to place one end of a screwdriver or steel rod against the bearing housing. Then place the other end against the ear. A loud, irregular grinding, clicking, or scraping noise indicates trouble. As stated before, the degree of reliance in the results of this test depends on the tester's experience.

Vibration analysis equipment is also used to test conditions of motor bearings. Initial baseline surveys are taken. Then periodic checks are made by maintenance personnel. The periodic checks determine if the bearings are still in normal working condition or if they are failing. Consult your ship's PMS documentation for the method used for vibration analysis on your ship.

Checking the movement of a motor or generator shaft also gives a good indication of bearing wear. Figure 12-8, item A, shows how to get a rough check of vertical movement. If the motor shaft has too much vertical movement, it has worn bearings. Figure 12-8, item B, shows how to get a rough check of generator end-play movement. Too much movement is corrected with bearing shims.

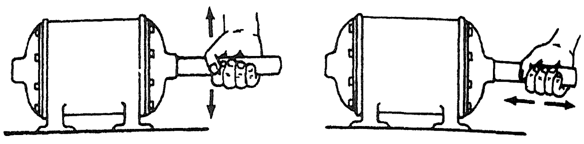

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Figure 12-8.—Checking motor or generator shaft; (A) vertical movement and (B) end-play movement.

LUBRICATION.—One cause of motor and generator failure is overlubrication. Forcing too much grease into the bearing housing seals and onto the stationary windings and rotating parts causes overheating. It also causes deterioration of insulation. Eventually this results in electrical grounds and shorts. Overheating will also cause rapid deterioration of the grease and ultimate destruction of a bearing. To avoid the results of overlubrication, add new lubricant only when necessary. *Naval Ships' Technical Manual,* Chapter 244, provides additional guidance for lubrication of motors and generators.

The frequency to add new grease depends upon the service of the machine and the tightness of the housing seals. A lot of grease coming through the shaft extension end of the housing probably indicates excessive leakage inside the machine.

Grease cups are removed from motors and generators to prevent greasing by personnel in operating spaces. Pipe plugs are inserted in the place of the grease cups. The pipe plugs are replaced temporarily with grease cups during lubrication (figure 12-9). (Removable grease cups should remain in the custody of responsible maintenance personnel.) Make sure the grease cups are clean. After the grease is added and before the pipe plugs are replaced, clean the pipe plugs.

The preferred method of adding grease calls for disassembly of the bearing housing. Though not recommended, renewing the bearing grease without at least partially disassembling the housing can be tried under certain conditions. These conditions are listed in the next section after the preferred method.

Renewal of Grease by Disassembling the Bearing Housing.—The extent of disassembly necessary depends upon the construction of the

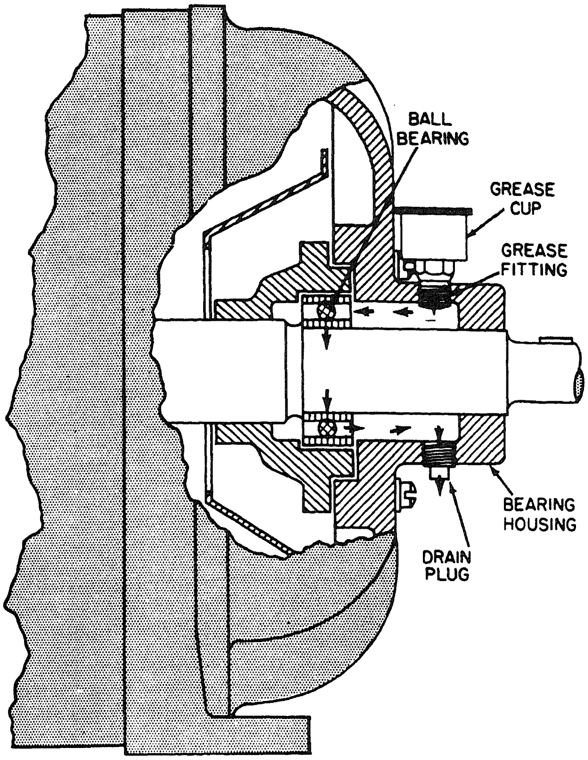

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Figure 12-9.—Grease-lubricated ball bearings.

bearing. For the usual construction, you should disassemble bearings with outer bearing caps as follows.

1. Remove the outer bearing cap after thoroughly wiping all exterior surfaces.

2. Remove old grease from all accessible portions of the housing and clean them thoroughly. Be careful not to introduce dirt or lint into the housing of the bearing.

3. Flush out the bearing cap with clean, hot (about 120 °F) kerosene, diesel fuel oil, or dry-cleaning fluid. Then flush out with a light mineral oil (not heavier than SAE 10, similar to diesel lubricating oil).

4. Where practical, plug all hoses leading into the interior of the machine. Flush out the complete housing with the outer bearing cap removed. Use the solvents and procedure in step 3, unless the cleaning fluids may leak into the windings. In such cases, omit this step.

5. Drain the mineral oil thoroughly; then pack the housing half full with fresh, clean grease.

6. Fill the grease cup with fresh, clean grease. Screw it down as far as it will go. KEEP THE MACHINE RUNNING CONTINUOUSLY.

7. Repeat step 6 above until clean grease runs out of the drain hole.

8. At this point stop putting in grease. Run the motor until the grease stops running out of the drain hole. THIS STEP IS VERY IMPORTANT.

9. Clean any drain pipes that have been removed and replace them.

10. Replace the drain plug.

Renewal of Grease Without Disassembling the Bearing Housing.—Do not try to add new grease without at least partial disassembly of the bearing housing unless the following conditions apply.

1. The machine is horizontal. In vertical machines, there are no adequate means of protecting the windings against displaced lubricant.

2. A suitable fitting is provided for admitting grease. If a grease-gun fitting is provided, replace it by a grease cup.

3. The drain hole on the bearing housing is accessible. Drain pipes do not permit proper escape of displaced grease. Remove them when renewing grease.

4. The machine is run continuously while renewing grease. Sometimes the machine cannot be run continuously during the greasing period without injuring the driven auxiliary or endangering personnel. In such cases, you must disassemble the bearing housing to renew grease.

If the above conditions apply, renew the grease in assembled bearing housings by the following method.

1. Run the machine to warm up the bearings.

2. Wipe any dirt away from the area around the grease fittings.

3. Remove the drain plug and drain pipes from the drain hole in the bearing housing.

4. With a clean wire, screwdriver, or similar tool, clear the drain hole of all hardened grease.

5. Remove the grease cup. Clear the grease inlet hole of hardened grease.

6. With the motor running, pack the grease cup with grease and screw the grease cup down all the way.

7. Repeat step 6 until grease runs out of the drain hole.

8. Run the motor until the grease stops running out of the drain hole.

9. Replace the drain plug and drain pipes.

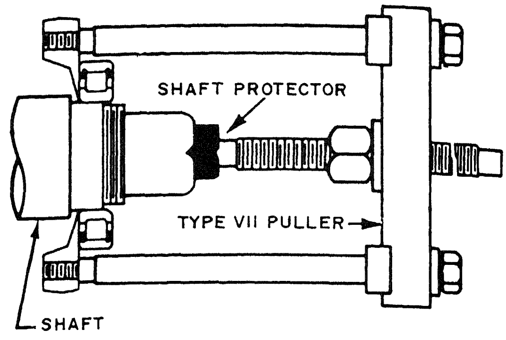
Grease-Lubricated Ball Bearings.—Lubricate ball bearings that normally operate at a temperature of 194 °F (90 °C) or below with grease following Department of Defense Specification DOD-G-24508. Lubricate ball bearings that normally operate at a higher temperature with a silicone grease following Military Specification MIL-L-15719. Each machine requiring the silicone grease has a caution plate, USE HIGH TEMPERATURE GREASE. The plate is attached near the grease fitting.

NEVER DISASSEMBLE OR CLEAN DOUBLE-SHIELDED OR DOUBLE-SEALED BALL BEARINGS. These bearings are prelubricated. Cleaning will remove the lubricant from the bearings or at least dilute the lubricant. Eventually, it will no longer possess its original lubricating qualities.

Permanently lubricated ball bearings require no greasing. You can recognize equipment using these bearings by the absence of grease fittings or provision for attaching grease fittings. When permanently lubricated bearings become inoperative, replace them with bearings of the same kind. If not already provided, attach nameplates (DO NOT LUBRICATE) to the bearing housing with sealed bearings.

CLEANING BALL BEARINGS.—Open, single-shielded, or single-sealed ball bearings can be cleaned. This should be done only in an emergency when a suitable replacement is not available. It is difficult to remove dirt from ball bearings. Unless carefully done, more dirt may get into the bearings than is removed.

In cleaning an open, single-shielded, or single-sealed bearing, take the bearing off with a bearing puller. Apply the puller to the inner race of the bearing. Figure 12-10, item A and item B, shows two types of bearing pullers. Both apply the pulling pressure to the inner race of the bearing. Removal of bearings by pulling on the outer race tends to make the balls dent the raceway even when the puller is used. Sometimes a bearing may be subjected to temperatures that distort the race and balls. In this case, the race may shrink to a shaft more tightly than the original fit. Do not damage the shaft when removing the bearing. Use soft centers that are usually provided with a bearing removal kit. If not, you can make them from soft metal, such as zinc or brass.



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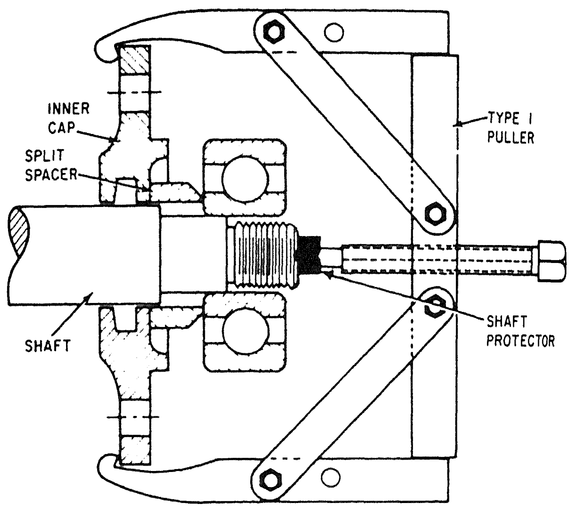

B

73.325A & B

Figure 12-10.—Types of bearing pullers, (A) type VII, (B) type I.

After removal, thoroughly clean the bearing. A good cleaner to use is standard solvent or clean

oil. Soak the bearing in the cleaner long enough to dislodge dirt or caked grease from around balls and separators. After cleaning the bearing, wipe it carefully with a dry, lint-free cloth. If you use compressed air for drying, direct the air stream so the bearing does not spin. Because dry bearings rust quickly, protect the bearing at once. Coat it with clean, low-viscosity lubricating oil. Refer to *Naval Ships' Technical Manual*, Chapter 244, for additional guidance on bearing cleaning.

Rotate the inner ring slowly by hand, and if the bearing feels rough, repeat the cleaning. If the bearing still feels rough when turned slowly by hand, it is not fit for use. Renew it.

BEARING INSTALLATION.—There are two acceptable methods for installing bearings: arbor press and heat. Both methods are discussed in more depth in *Naval Ships' Technical Manual*, Chapter 244.

Arbor Press Method.—When available and adaptable, you can use an arbor press if you take proper precautions. Place a pair of flat steel blocks under the inner ring or both rings of the bearing. Never place blocks under the outer ring only. Then line up the shaft vertically above the bearing. Place a soft pad between the shaft and press ram. After you make sure the shaft is started straight in the bearing, press the shaft into the bearing. Press until the bearing is flush against the shaft or housing shoulder. When pressing a bearing onto a shaft, always apply pressure to the inner ring; when pressing a bearing into a housing, always apply pressure to the outer ring.

Heat Method.—You can heat a bearing in an oven or furnace to expand the inner ring for assembly. This method ensures uniform heating around the bearing.

Heat the bearing in an IR oven or a temperature-controlled furnace at a temperature not to exceed 200°F. Do not leave the bearing in the oven or furnace after the inner race has expanded the desired amount. Prolonged heating could deteriorate the prelubrication grease. You can also heat the bearing in oil at 200°F until expanded. Then slip it on the shaft. This method is not as desirable as the others. Do not use it unless absolutely necessary. There are disadvantages of using the hot-oil method. They are the lack of temperature controls and increased chances of enlarging the bearing, deteriorating the grease, or contaminating the grease by use of dirty oil.

Additional methods of bearing installation are explained in *Naval Ships' Technical Manual*, Chapter 244.

Friction Bearings

There are three types of friction bearings. They are RIGHT LINE, JOURNAL, and THRUST. In the RIGHT LINE type, the motion is parallel to the elements of a sliding surface. In the JOURNAL type, two machine parts rotate relative to each other. In the THRUST type, any force acting in the direction of the shaft axis is taken up. The SS generators are equipped with journal bearings, commonly called SLEEVE bearings. The bearings may be made of bronze, babbitt, or steel-backed babbitt. Preventive maintenance of sleeve bearings requires periodic inspections of bearing wear and lubrication.

WEAR.—You can obtain bearing wear on a sleeve bearing by measuring the air gap at each end of the machine. Use a machinist's tapered feeler gauge. Use a blade long enough to reach into the air gap without removing the end brackets of the machine. For a.c. machines, clean at least three or more spots at equal intervals around the circumference on the stator. Take the air gap measurement between a cleaned spot on the rotor and a cleaned spot on the stator. Turn the rotor to bring the cleaned spot of the rotor in alignment with the cleaned spots on the stator. Compare these readings with the tolerance stated by the manufacturer's instruction book.

TROUBLE ANALYSIS.—The earliest sign of sleeve bearing malfunction normally is an increase in the operating temperature of the bearing. RTDs are usually inserted in the bearing as a means of visually indicating the temperature of the bearing. Operating personnel take temperature readings hourly on running machinery. Therefore, after checking the temperature, make a follow-up check by feeling the bearing housing whenever possible. Operating personnel must thoroughly familiarize themselves with the normal operating temperature of each bearing. They have to

recognize any sudden or sharp changes in bearing temperature. Many large generators are provided with bearing temperature alarm contactors. These are incorporated in the ship's alarm system. The contactor is preset to provide an alarm when proper bearing temperature is exceeded. If bearing malfunction is indicated, secure the affected machinery as soon as possible. Unload overheated sleeve bearings, if possible, without stopping the unit. If stopped immediately, the bearing may seize. The best way to limit bearing damage is to keep the unit running at a light load. Supply it with plenty of cool, clean oil until the bearing cools down.

Sometimes the permissible operating temperature is often too high to be estimated by the sense of touch. Then you should take temperature measurements to determine whether a bearing is overheated. A thermometer securely fastened to the bearing cover or housing usually gives satisfactory bearing temperature measurements. You can use this method on machines not equipped with bearing temperature measuring devices. Do not insert a thermometer into a bearing housing; it may break. Then disassembly would be necessary to remove glass and mercury.

Any unusual noise in operating machinery may also indicate bearing malfunction. Whenever a strange noise is heard in the vicinity of operating machinery, make a thorough inspection to determine its cause. Excessive vibration will occur in operating machinery with faulty bearings. Make inspections at frequent intervals to detect faulty bearings as soon as possible.

BRUSHES

The brushes used in generators are one or more plates of carbon, bearing against a collector ring (slip ring). They provide a passage for electrical current to an external circuit. The brushes are held by brush holders mounted on studs or brackets attached to the brush-mounting ring or yoke. The brush holder studs or brackets and brush-mounting ring comprise the brush rigging. The brush rigging is insulated from, but attached to, the frame or one end bell of the machine. Flexible leads (pigtails) connect the brushes to the terminals of the external circuit. An adjustable spring is generally provided to maintain proper pressure of the brush on the slip ring. This is to effect good commutation.

Brushes are manufactured in different grades to meet the requirements of the varied types of service. The resistance, ampere-carrying capacity, coefficient of friction, and hardness of the brush are set by the maximum allowable speed and load of the machine.

Correct Brush Type

The correct grade of brush and correct brush adjustment are necessary to avoid commutation trouble.

Use the grade of brush shown on the drawing or in the technical manual applicable to the machine. An exception to this is when Naval Sea Systems Command instructions issued after the date of the drawing or technical manual state otherwise. In such cases, follow the Naval Sea Systems Command instructions.

Brush Care

Securely connect all brush shunts to the brushes and the brush holders. Brushes should move freely in their holders. They should not be loose enough to vibrate in the holder. Before replacing a worn brush with a new one, clean all dirt and other foreign material from the brush holder.

Replace with new brushes, all brushes that

- are worn or chipped so they will not move properly in their holders;

- have damaged shunts, shunt connections, or hammer clips;

- have riveted connections or hammer clips and are worn to within 1/8 inch of the metallic part;

- have tamped connections, are without hammer clips, and are worn to one half or less of the original length of the brush; or

- have spring-enclosed shunts and are worn to 40 percent or less of the original length of the brush. This does not include the head that fits into one end of the spring.

Where adjustable brush springs are of the positive gradient (torsion, tension, or compression) type, adjust them as the brushes wear. This keeps the brush pressure almost constant. Springs of the coiled band, constant pressure type, and some springs of the positive gradient type are not adjustable. On these you have to change springs. Brush pressure should follow the manufacturer's technical manual. Pressures as low as 1 1/2 psi of contact area may be specified for large machines. Pressure as high as 8 psi of contact area may be specified for small machines. When technical manuals are not available, a pressure of 2 to 2 1/2 psi of contact area is recommended. To measure the pressure of brushes operating in box-type brush holders, insert one end of a strip of paper between the brush and slip ring. Use a small brush tension gauge (such as the 0- to 5-pound indicating scale) to exert a pull on the brush toward the brush holder axis as shown in figure 12-11.

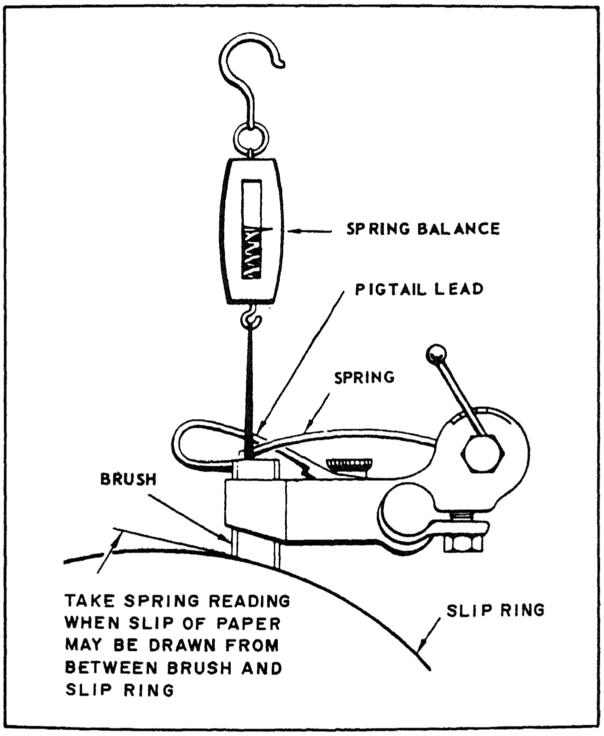

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Figure 12-11.—Measuring brush tension.

Note the reading of the gauge when you can pull the strip of paper from the brush and slip ring without offering resistance. This reading divided by the contact area may be considered to be the unit operating pressure.

A.C. ROTORS

Basically, the rotor of an a.c. motor is a squirrel cage rotor or a wound rotor. The squirrel cage rotor usually has heavy copper or aluminum bars fitted into slots in the rotor frame. These bars are connected to short-circuiting end rings by being cast or brazed or welded together (figure 12-12). Often the cage rotor is made by die-casting the rotor bars, end rings, and cooling fans into one piece. The cage rotor requires less attention than the wound rotor. However, the cage rotor should be kept clean. Check the rotor bars periodically for evidence of loose or fractured bars. Localize overheating.

Wound rotors are not used on gas turbine ships, so we will not discuss them in this book. For more information on wound rotor motors, refer to *Electrician's Mate 3 & 2*, NAVEDTRA 10546-E1.

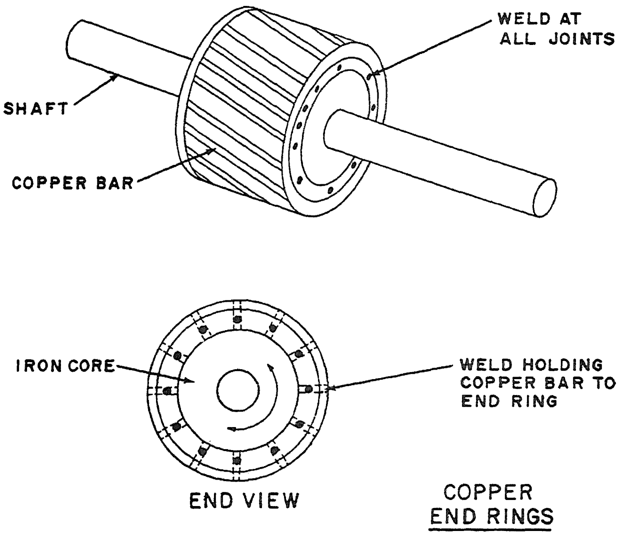

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Figure 12-12.—Squirrel cage rotor.

A.C. STATOR WINDINGS

A.c. stator windings require the same careful attention as other electrical windings. For a machine to function properly, the stator windings must be free from grounds, short circuits, and open circuits.

A short circuit in the stator of an a.c. machine produces smoke, flame, or the odor of charred insulation. Secure the machine immediately. Conduct tests to find the reason for the abnormal condition.

The first and easiest test that you should conduct is the insulation resistance of the winding. This test is made with a megohmmeter or similar resistance-measuring instrument. Connect one instrument lead to ground and the other to each motor lead. (NOTE: The motor should be disconnected from ship's cabling before doing this test.) Crank the meter handle and read the scale on the meter face. If the insulation resistance is 1 megohm or above, the stator is not grounded. Make other tests to locate the trouble.

Next test for continuity with an ohmmeter. Connect the test leads to any two motor leads and then to the next two leads. Do this until all leads have been tested for continuity between each other. Whether the motor is wye- or delta-connected, you should get nearly zero indication on the ohmmeter between any two leads. A high resistance reading between any two leads is a good sign of an open phase winding.

For your next check, look for mechanical difficulties, such as frozen bearings or a frozen pump. First disconnect the motor from the driven unit. Spin the motor shaft to see if it is free to turn. Then check the driven end for freedom of movement. If the driven end is frozen, stop checking. Inform the maintenance person responsible for the driven end of your findings.

If the stator windings are burned out or opened, disassemble the motor. The proper procedure for disassembly is given later in this section.

A visual inspection of the stator will usually show where the trouble lies. If the stator is burned out, rewind it. Sometimes just one phase is open. Then you can make an emergency repair by carefully soldering the opened leads back together. Be extra careful in soldering these leads. Further damage could result if they are inadvertently shorted. After making this emergency repair, test the stator winding with low voltage to check the phase balance. (NOTE: This repair is only recommended in an extreme emergency, not as a normal repair.)

DISASSEMBLY AND REASSEMBLY OF MOTORS AND GENERATORS

When you have to disassemble and reassemble a large motor or generator, follow the procedures in the manufacturer's instruction book. Exercise care to prevent damage to any part of the machine. Support the machine rotors while they are being moved or when stationary. Use slings or blocking under the shaft or a padded cradle or thickly folded canvas under the core laminations. To lift the rotor, place rope slings under the shaft, clear of the bearing journals. Separate the rope slings by a spreader to prevent the slings coming in contact with the a.c. rotor or d.c. armature coils. Construction of the shaft may not provide room for a sling except around the journals. Then protect them with heavy paper or canvas before applying the sling. When you have to lift the whole unit (stator and rotor) by lifting the stator, tightly shim the bottom of the air gap. Do this unless both ends of the shaft are supported in bearings. By rough or careless handling of bars or hooks, you can do a lot of damage during disassembly and reassembly. You can do more damage to a machine than it will receive in years of normal service.

Never be hasty or careless in disassembling a generator or motor. Use the proper tools. Label the parts as you dismantle them. Store them in an orderly arrangement in a safe place. Note down the necessary information so you will have no trouble in reassembly. The process of reassembling a machine should be the reverse of taking it down.

Follow a few simple steps when disassembling a motor or generator. Make sure you mark the frame and mating end bells (figure 12-13). Use a different mark for each end. When separating the end bells from the frame, use a mallet or block of wood with a hammer (figure 12-14). Never pry mating surfaces apart with a metal object such as a screwdriver. To prevent damaging the brushes, lift them from the commutator and/or slip rings (if present) before removing the rotor.

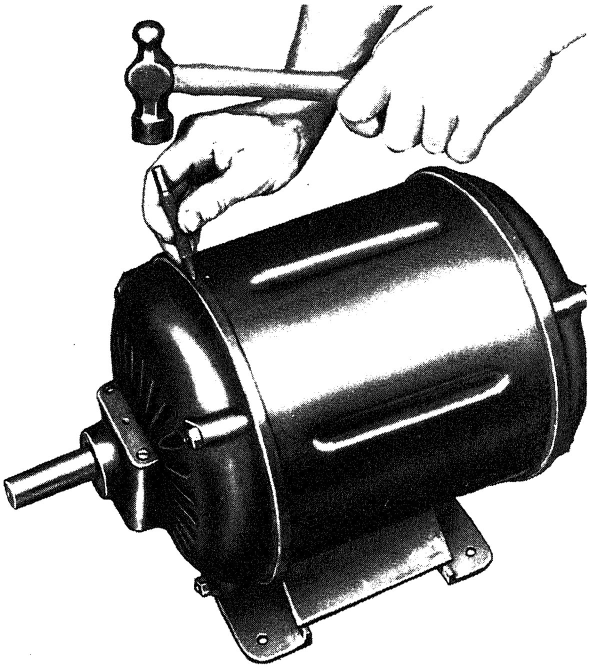

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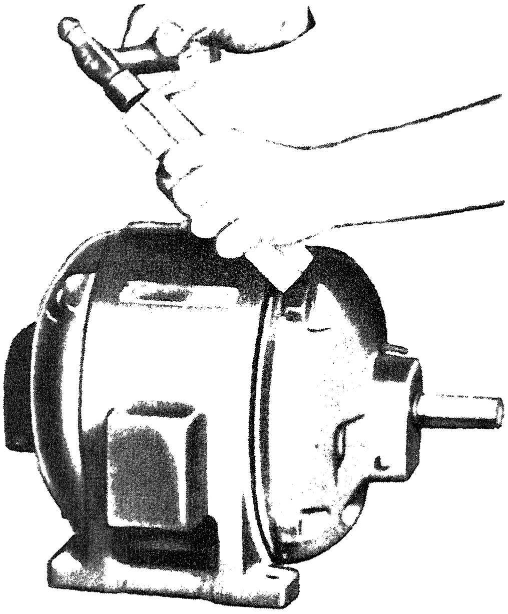
Figure 12-13.—Marking a motor frame and end bell.



73.223.2
Figure 12-14.—Parting end bells with a hammer and wood block.

Protect the windings, when necessary, by inserting thin strips of waxed paper between the rotor and the stator.

When removing bearings, you can use an arbor press if you take proper precautions. Place a pair of flat steel blocks under the inner ring or both rings of the bearing. Never place blocks under the outer ring only. Then line up the shaft vertically above the bearing. Place a soft pad between the shaft and press ram. After making sure the shaft is started straight in the bearing, press the shaft into the bearing. Do this until the bearing is flush against the shoulder of the shaft. You may use a gear puller to remove a rotor bearing. However, be careful.

Never remove the bearings unless they are in poor condition, or need to be removed for removal of the end bells. When taking off a ball bearing to use it again, be careful to apply pressure to the inner race only. If pressure has been applied to the outer race, you discard the bearing.

Never use a cleaning solvent on a sealed or a semisealed ball bearing. Store these bearings in a clean piece of waxed paper until you are ready to use them.

Clean the end bells with a brush and an approved solvent. Check them for cracks, burrs, nicks, and excessive paint, as well as for dirt.

60-HERTZ DISTRIBUTION SYSTEM COMPONENTS

After 450-volt a.c. 60-Hz power is generated by the SS generators, the power must be distributed throughout the ship. Control, switching, and protective devices are installed to effectively control this power. These devices are as small and simple as fuses or as large and complex as GBs. The entire distribution system is interconnected by cables. They vary from very large bus tie cables to small cables feeding receptacles. These cables are labeled by a numbering system that allows rapid identification for repair, isolation, and troubleshooting. We will discuss this system later in this section.

GENERATOR CIRCUIT BREAKERS

The GB is the main protective device for the SS generator. Other devices are incorporated with the breaker allowing it to protect the generator from many undesirable conditions. Some of these are reverse power relays, synchronizing monitors, overcurrent relays, and interrupting fuses. Built-in time delay trips of the breakers and these protective devices provide the maximum protection for the valuable generator set. It is better for a GB to open than risk a major generator casualty such as a fire. Table 12-1 is a listing of characteristics of the GBs found on gas turbine ships.

All CBs on gas turbine ships are air type. That is, their contacts are interrupted by air. The GBs are all ACB type.

Type ACB CBs are used for either manual local closing or electrical remote closing. They have an open metallic frame construction mounted on a drawout mechanism. They are normally applied where heavy loads and high short circuit currents are available. Figure 12-15 shows the external appearance of a type ACB CB.

Type ACB CBs connect SS generators to the power distribution system. They are used on bus ties and shore connection circuits. They are also used on some feeder circuits from the SS switchboard. When used for these purposes, the pilot device may be a device such as a reverse-power relay. Later in this chapter we will discuss other control devices that the breaker might use.

The CBs designed for high currents have a double-contact arrangement. The complete contact assembly has the main bridging contacts and the arcing contacts. All current-carrying contacts are high-conductivity, arc-resisting silver or silver alloy inserts.

Each contact assembly can hold the arcing to a minimum and extinguish the arc as soon as possible. The arc control section is called an arc chute or arc runner. The contacts are so arranged that when the circuit is closed, the arcing contacts close first. Proper pressure is maintained by springs to ensure the arc contacts close first. The main contacts then close.

When the circuit opens, the main contacts open first. The current is then flowing through the arc contacts, which prevents burning of the

Table 12-1.—Generator Circuit Breaker Characteristics

CHARACTERISTIC	FFG-7	DD/DDG	CG
Breaker type	ACB-1600HR	ACB-3200HR	ACB-3200HR
Number of poles	3	3	3
Frequency	60 Hz	60 Hz	60 Hz
Continuous rating	1,600 AMP	3,200 AMP	4,000 AMP
Long time delay	3,200 AMP	6,400 AMP	6,400 AMP
Short time delay	4,000 AMP	8,000 AMP	10,000 AMP
Instantaneous trip	24,000 AMP	40,000 AMP	43,000 AMP
Closing circuit	115 VAC	DC motor	450 VAC
Opening circuit	115 VAC	DC motor	115 VAC
Protective circuits	reverse power and under voltage	under frequency, under voltage, reverse power, fault current and synchronizing monitor.	under frequency, under voltage, reverse power, fault current, TOPS, and synchronizing monitor.

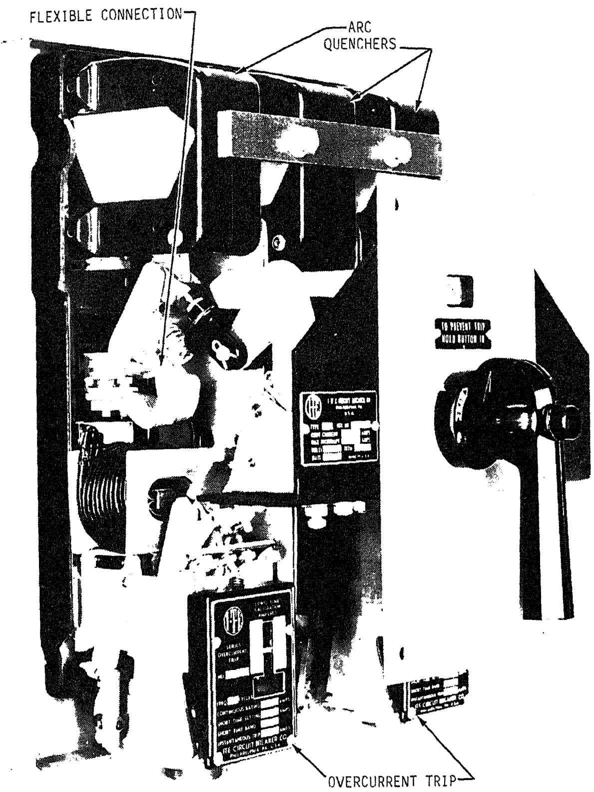


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Figure 12-15.—Type ACB circuit breaker.

main contacts. When the arc contacts open, they pass under the front of the arc runner. This causes a magnetic field to be set up, which blows the arc up into the arc quencher. This quickly opens the circuit.

As stated before, type ACB CBs are available in both manually (hand-operated) and electrically operated types. Electrically operated ACB CBs may be operated from a remote location. The high interrupting types are electrically operated. This is because personnel do not have to approach them to open or close the circuit.

NOTE: Do not work on any CB, regardless of type, without opening the circuit. Remember, some terminals have voltage applied to them when the breaker is open. Aboard ship, power may be supplied to either end of the CB.

BUS TIE CIRCUIT BREAKERS

The BTBs connect switchboard buses together through cables known as bus ties. Normally, a BTB is on each end of a bus tie. They are located in the switchboards. The BTBs on gas turbine ships are type ACB CBs. However, they do not have all the protective devices found on GBs such as reverse power or instantaneous tripping. Table 12-2 is a listing of characteristics of BTBs found on gas turbine ships.

The BTBs are used to isolate switchboards. They also can be used to parallel across when two live switchboards are connected with different

Table 12-2.—Bus Tie Circuit Breaker Characteristics

CHARACTERISTIC	FFG-7	DD/DDG	CG
Breaker type	ACB-1600HR	ACB-3200HR	ACB-3200HR
Number of poles	3	3	3
Frequency	60 Hz	60 Hz	60 Hz
Continuous rating	1,600 AMP	3,200 AMP	4,000 AMP
Long time delay	2,400 AMP	4,800 AMP	None
Short time delay	3,200 AMP	6,400 AMP	8,000 AMP
Instantaneous trip	None	None	None
Closing circuit	115 VAC	DC motor	450 VAC
Opening circuit	115 VAC	DC motor	115 VAC

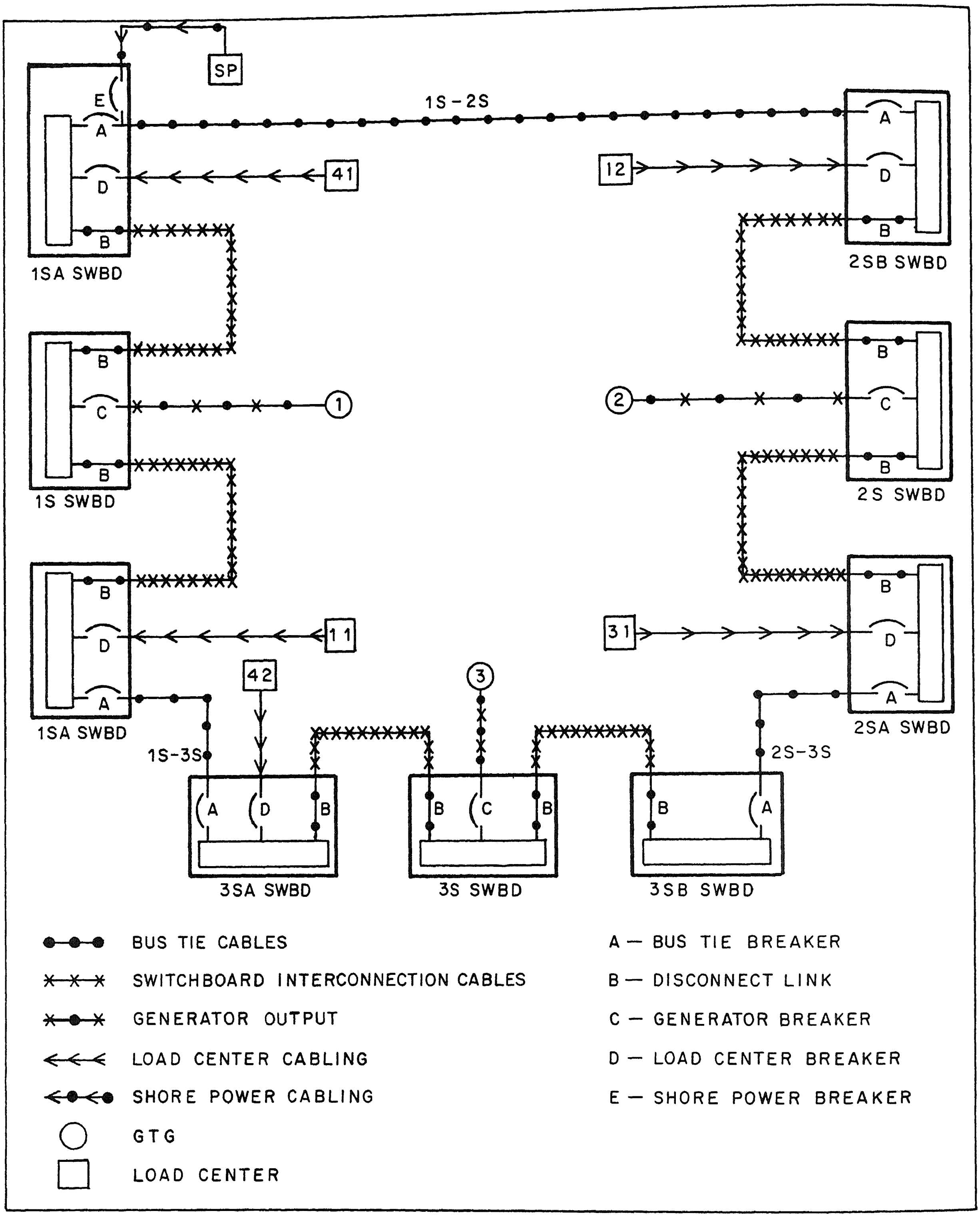

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Figure 12-16.—Ship's distribution system, DD-963 class ship.

power sources. Figure 12-16 is a diagram of a DD-963 distribution system. Note how bus ties are used to connect the switchboards together with a breaker at each end.

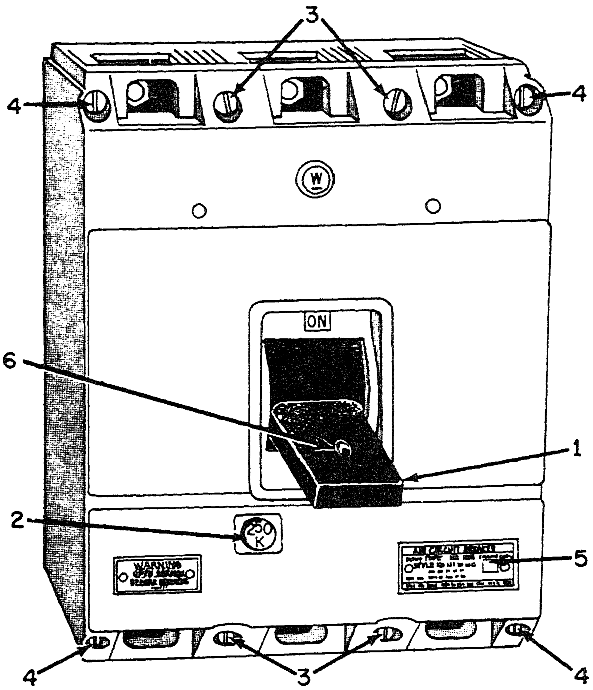
LOAD CENTER BREAKERS

Larger gas turbine ships use load centers located in remote locations of the ship. They are used to supply power to these areas. Use of load centers eliminates the use of a large number of long cables to feed remote areas. These load centers are similar in construction to the switchboard load sections. Since these load centers have many load breakers, the supply breakers that feed these centers must be large. The load center breakers on the ships with load centers are also type ACB. They are constructed on the same frame as the GBs and BTBs. But they have lower rated trip coils. The ACB-1600HR CBs are used to supply load centers. However, they are set up with two different trip ratings. Table 12-3 is the listing of the load center breaker characteristics. Refer to your ship's technical manuals for the amperage ratings of each load center breaker on your ship's switchboards.

SWITCHBOARD-MOUNTED LOAD BREAKERS

Power for all SS loads is distributed from switchboards (and load centers) by load breakers. These breakers are normally type AQB CBs with thermal magnetic trip and current limiting fuses. These breakers may be equipped with shunt trips for remote tripping by load shed or ventilation shutdown circuits.

Type AQB CBs (figure 12-17) are mounted in supporting and enclosing housings of insulating material. They have direct-acting automatic



1. Operating handle shown in latched position
2. Ampere rating marking
3. Mounting screws
4. Cover screws
5. Breaker nameplate
6. Cotter key hole

77.241

Figure 12-17.—AQB-A250 circuit breaker, front view.

Table 12-3.—Load Center Breaker Characteristics

CHARACTERISTIC	1,400 AMPERES	1,600 AMPERES
Breaker type	ACB-1600HR	ACB-3200HR
Number of poles	3	3
Frequency	60 Hz	60 Hz
Continuous rating	1,400 AMP	1,600 AMP
Long time delay	2,100 AMP	2,400 AMP
Short time delay	4,800 AMP	4,800 AMP
Instantaneous trip	None	None
Closing circuit	DC motor on DD-963/DDG-993	450 VAC on CG-47
Opening circuit	DC motor on DD-963/DDG-993	115 VAC on CG-47

tripping devices. They are used to protect single-load circuits and all feeder circuits coming from a distribution switchboard.

The following AQB breakers may be found on switchboards and distribution panels: AQB-A101, AQB-LF250, AQB-LF400, or AQB-LF800.

AQB-A250

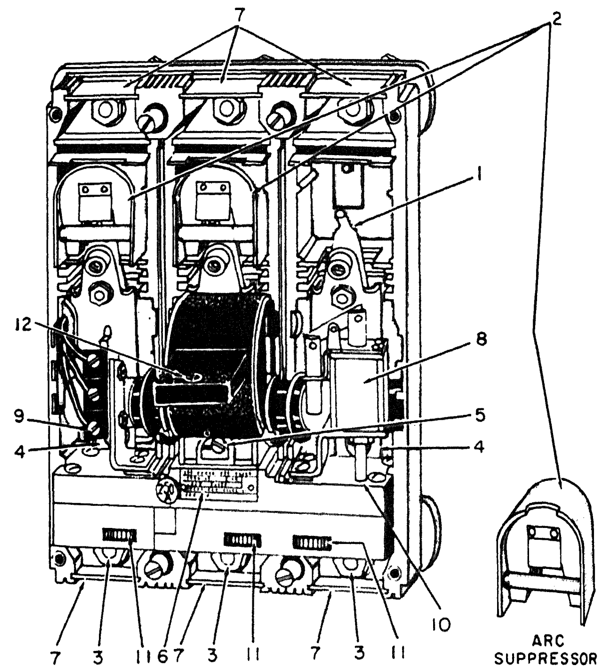
While most of the breakers you encounter are the limiting fuse type, we will discuss the A250 as a basis for discussion of other types. The outside dimensions of AQB-A250 breakers are the same for both the two-pole and three-pole CBs. They are designed for front or rear connections as required. They may be mounted so that you can remove the front without removing the CB cover. The voltage ratings of the AQB-A250 are 500 volts a.c. 60-Hz.

The 250 part of the CB type of designation indicates the frame size of the CB. In a 250-ampere frame size CB, the current-carrying parts of the breaker have a continuous rating of 250 amperes. Trip units (figure 12-18) for this breaker are available with current ratings of 125, 150, 175, and 250 amperes.

The trip unit houses the electrical tripping mechanisms, the thermal element for tripping the CB on overload conditions, and the instantaneous trip for tripping on short circuit conditions.

Also, 100-, 160-, and 250-ampere rating trip units with a special calibration are available with GBs. Regardless of the trip unit used, the breaker is still a 250-ampere frame size. The automatic trip devices of the AQB-A250 CB are trip free of the operating handle; in other words, the CB cannot be held closed by the operating handle if an overload exists. When the CB has tripped because of overload or short circuit, the handle rests in a center position. To reclose after automatic tripping, move the handle to the extreme OFF position. This resets the latch in the trip unit. Then move the handle to the ON position.

The AQB-A250 CB may have auxiliary switches, shunt trip (for remote tripping), or undervoltage release attachments when so specified. However, a shunt trip cannot be provided in the same breaker with an undervoltage release. This is because the shunt trip coil is momentary rated and must be connected in series

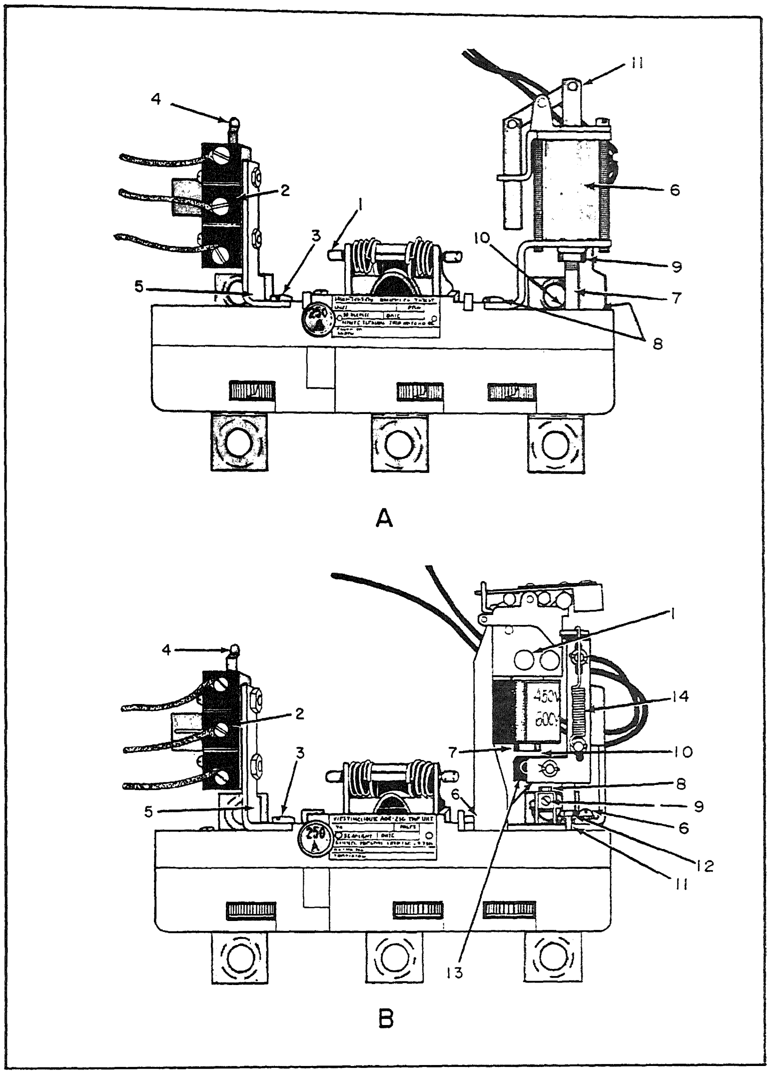


1. Stationary contact
2. Arc suppressors
3. Terminal stud nuts and washers
4. Trip unit line terminal screw-outer poles
5. Trip unit line terminal screw-center pole
6. Trip unit nameplate
7. Terminal barriers
8. Shunt trip or undervoltage device
9. Auxiliary switch
10. Hole for shunt trip or undervoltage release plunger
11. Instantaneous trip adjusting wheels
12. Cotter key hole

77.242

Figure 12-18.—AQB-A250 circuit breaker front view, cover, and arc suppressor removed.

with a CB auxiliary switch. Figure 12-19 shows a trip unit with shunt trip and a trip unit with undervoltage trip. The coil for a shunt trip has a dual rating for a.c. and d.c. voltages. But, the undervoltage trip coils are wound for a specified voltage, such as 450 a.c. or 250 d.c. They have rated pickup and dropout values. You can adjust the instantaneous trip setting of the AQB-A250 trip units by the instantaneous trip adjusting wheels. Though not shown in figure 12-19, these trip adjusting wheels are marked for five



1. Trip unit latch pin
2. Auxiliary switch
3. Auxiliary switch mounting screws
4. Auxiliary switch lever
5. Auxiliary switch mounting bracket
6. Shunt trip
7. Shunt trip tubular core
8. Shunt trip mounting screws
9. Tubular core lock nut
10. Hole for shunt trip push pin
11. Shunt trip plunger

(A)

1. Undervoltage release
2. Auxiliary switch
3. Auxiliary switch mounting screws
4. Auxiliary switch lever
5. Auxiliary switch mounting bracket
6. Undervoltage release mounting screws
7. Undervoltage release magnet
8. Armature travel adjusting screw
9. Set screw for armature adjusting screw
10. Armature-magnet air gap
11. Undervoltage release push rod
12. Lock nut for push rod
13. Undervoltage release armature
14. Armature retaining springs

(B)

77.243.244

Figure 12-19.—AQB-A250 trip unit: (A) with shunt trip and auxiliary unit; (B) with undervoltage release and auxiliary unit.

positions, LO-2-3-4-HI. The trip unit label (not shown) will list the instantaneous trip value obtainable for each marked position. You must make identical settings on each pole of the CB. NEVER remove a CB cover to perform adjustments while the CB is in the closed (ON) position.

Terminal mounting block assemblies used with the CB (figure 12-20) for drawout mounting have terminal studs in terminal mounting blocks of insulating material. The terminals of the CB have slip-type connectors that engage the terminal studs (figure 12-20). Two mounting blocks are usually required for each CB. This method of connecting a CB to a bus or circuit is known as a back-connected CB. The CBs that have solderless connectors attached to their terminal are commonly called front-connected CBs. The interrupting rating of the AQB-A250 CB is 20,000 amperes at 500 volts a.c. or 15,000 amperes at 250 volts d.c.

AQB-LF250

The AQB-LF250 CB (figure 12-21) combines the standard AQB CB and a current limiting fuse

Nomenclature for figure 12-21

1. Operating handle shown in latched position
2. Ampere rating marker
3. Breaker mounting screws
4. Cover screws
5. Breaker nameplate
6. Fuse unit assembly
7. Fuse unit mounting screws
8. Fuse unit nameplate
9. Breaker cover
10. Cotter key hole

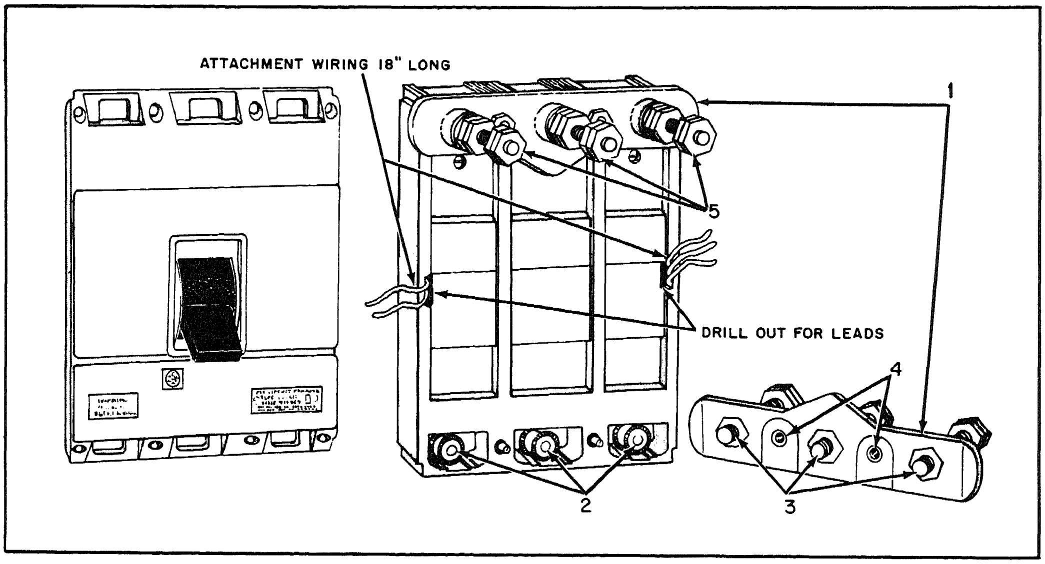
(A)

1. Breaker operating handle shown in tripped position
2. Ampere rating marker
3. Breaker mounting screws
4. Cover screws
5. Current limiting fuses
6. Fuse unit assembly
7. Fuse unit interlock pin
8. Trip lever
9. Fuse slip-on connectors
10. Fuse retaining block screws
11. Instantaneous trip adjusting wheels

(B)

1. Fuse retaining block
2, 3, & 4. Current limiting fuses
5. Extended plunger of blown fuse
6. Retracted plunger of unblown fuse
7. Fuse plunger lever
8. Fuse unit tripper bar
9. Fuse unit tripper bar lever
10. Fuse interlock pin
11. Fuse unit housing

(C)



1. Terminal mounting blocks (2 required)
2. Slip-type connectors
3. Terminal studs
4. Terminal mounting block inserts for breaker mounting bolts
5. Terminal stud nuts

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Figure 12-20.—AQB-A250 circuit breaker rear view, with terminal mounting block.

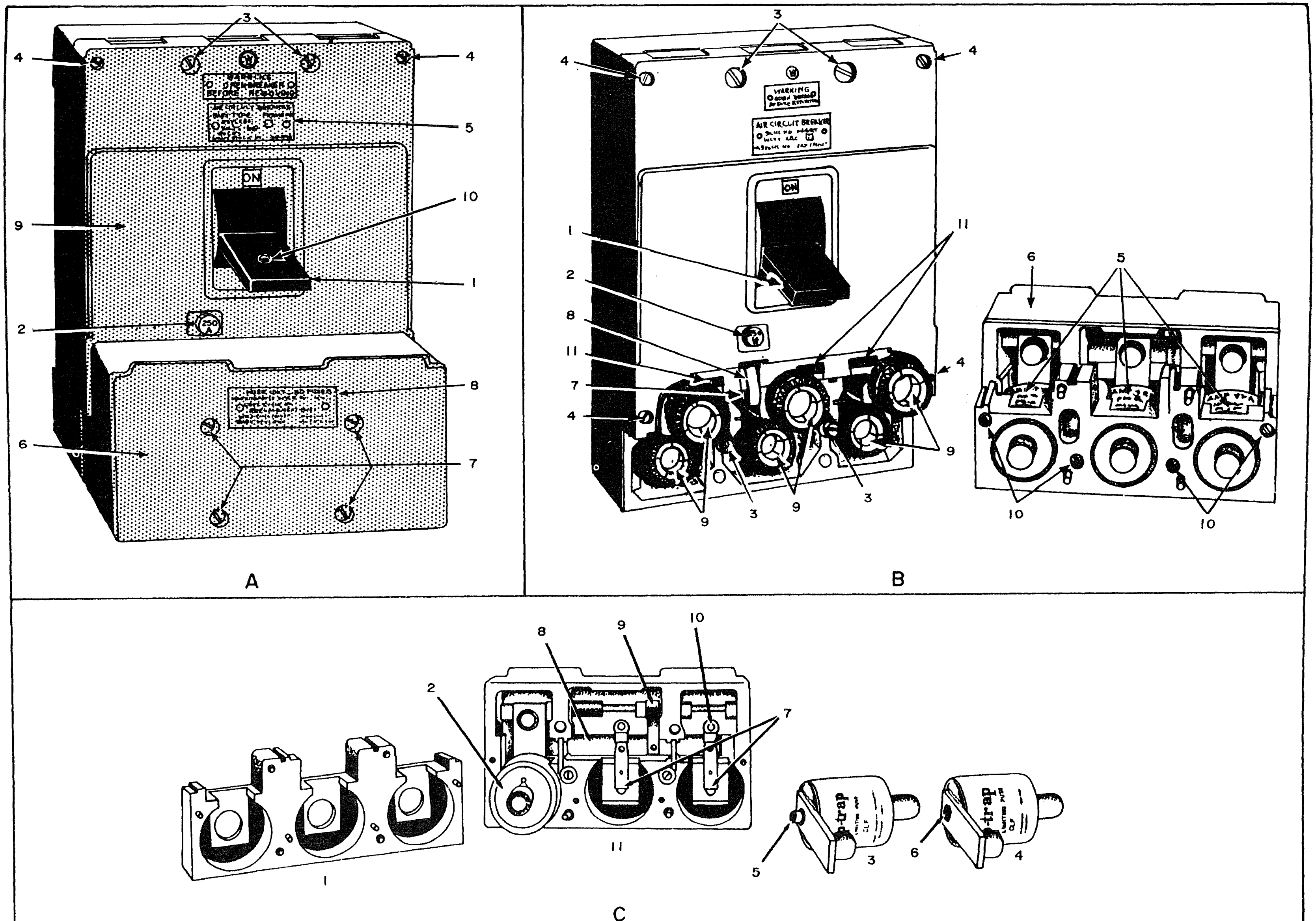

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Figure 12-21.—AQB-LF250 (A) front view (B) front view with fuse unit removed, and (C) current limiting fuse unit.

unit. This fuse interrupts the circuit when the current is in excess of the interrupting rating of the breaker. The AQB-LF250 CB is constructed as one compact unit. It incorporates the current limiting fuses (figure 12-21, item B) as integral parts of the CB. The common trip features of the AQB-A250 CB are retained. Trip units from 125 to 250 amperes are available for use in the AQB-LF250.

The current limiting fuse unit trips the breaker and opens all poles if any current limiting fuse is blown. (See figure 12-21, item C.) After a fuse has blown, you cannot reclose the CB until the blown fuse is replaced. Any attempt to remove the fuse unit when the CB is in the closed position will automatically trip the breaker.

The AQB-LF250 CB is interchangeable with the AQB-A250 CB except for the front panel. A larger cutout is required in the switchboard front panel to accommodate the fuse unit of the AQB-LF250.

The AQB-LF250 CB is a 250-ampere frame size. However, the CB has an interrupting rating of 100,000 amperes at 500 volts a.c. The AQB-A250 CB interrupting rating is 20,000 amperes at 500 volts a.c.

The AQB-A250 CB could be either front- or back-connected. However, the AQB-LF250 is designed only for back (drawout type) connection. It uses the same type of slip connectors and terminal studs as shown in figure 12-20.

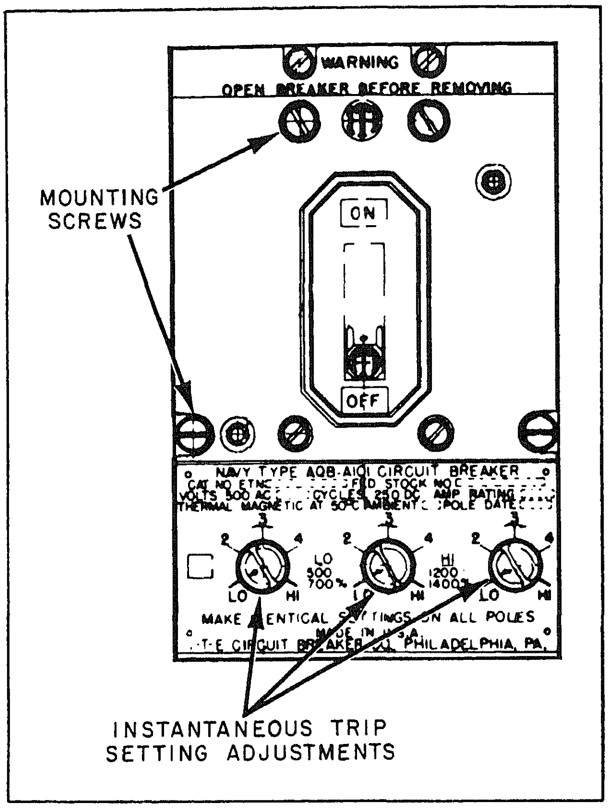
AQB-A400 and AQB-A800

The AQB-A400 and AQB-A800 CBs are very similar in design to the AQB-A250 CBs. The major difference is only in size and current capacity. Normally, these breakers will be combined with limiting fuses and are designated AQB-LF400 and AQB-LF800. In some applications, these breakers are equipped with a motor operator for remote operation. For additional information, consult your ship's switchboard technical manuals.

AQB-A101

The AQB-A101 and the fuse-type AQB-A101F (figure 12-22) are the smallest CBs found on the switchboard. They are designed to carry up to 100 amperes in continuous service. When equipped with a fuse unit, the short circuit interrupting current rating is 100,000 amperes. The breakers are rated by the size of the trip element installed. This is dependent on the service of the breaker. The ratings may be between 15 and 100 amperes.

The breaker houses the mechanism that provides the mechanical opening and closing, the thermal element for tripping an overload, and the instantaneous trip for tripping under short circuit conditions. The AQB-A101F differs only in having a mechanical device that causes the breaker to trip when the fuse unit is removed before opening the CB. These breakers have adjustable settings. These settings can change the instantaneous trip setting. The adjustments are on the



1. Mounting screws
2. Instantaneous trip
3. Setting adjustments

293.112

Figure 12-22.—AQB-A101 circuit breaker, front view.

front of the breaker. They have five settings: LO-2-3-4-HI. Normally, these are preset. If you have to adjust them, adjust them with the breaker open.

The AQB-A101 is normally back-connected. It is the plug-in type. Remove the breaker only when power is secured to the panel or switchboard that it is mounted in.

Circuit Breaker Maintenance

Attachable metal locking devices are available. They can be attached to the handles of type AQB CBs to prevent accidental operation. All breaker handles are now provided with a 3/32-inch hole. This allows you to fasten the locking device with a standard cotter pin. *Naval Ships' Technical Manual*, Chapter 300, lists the stock numbers for three different sizes of breaker handle locking devices.

The CBs require careful inspection and cleaning at least once a year. (More frequent cleaning is needed if they are subjected to unusually severe service conditions.) The special inspections follow.

No work should be undertaken on CBs without first obtaining approval of the electrical or engineer officer, and only after a thorough review of the applicable technical manual, plus Chapter 300 of *Naval Ships' Technical Manual*.

Before working on a CB, be aware of its time-delay characteristics. Know if short time, long time, or instantaneous trip is provided. The adjustments for selective tripping of most CBs are made and sealed at the factory. Changes should not normally be made to their trip settings. These changes may completely disrupt their intended functions of protection. Improper tripping action is corrected best by replacement of the entire breaker assembly. This is best especially where trouble is encountered in the compact assemblies.

Carefully make a special inspection of each pair of contacts after a CB has opened on a heavy short circuit. Before working on a CB, de-energize all control circuits to which it is connected; the procedure differs somewhat with the type of mounting that is used. For example, before work is done on drawout CBs, switch them to the open position. Then remove them. Before working on fixed-mounted CBs, open the disconnecting switches ahead of the breakers. Sometimes disconnecting switches are not provided for isolating fixed-mounted CBs. In these cases, de-energize the supply bus to the CB, if practical, before inspecting or doing any work on the CB.

Contacts are the small metal parts especially selected to resist deterioration and wear from the inherent arcing. The arcing occurs in a CB while its contacts are opening and carrying current at the same time. When firmly closed, the contacts must not arc.

Contact materials have been subjected to constant research, resulting in various products. These range from pure carbon or copper to pure silver. Each is used alone or as alloys with other substances. Modern CBs have contacts coated with silver, or silver mixed with cadmium oxide, or silver and tungsten. The two latter silver alloys are extremely hard and resist being filed. Fortunately, such contacts made of silver or its alloys conduct current when discolored (blackened during arcing) with silver oxide. The blackened condition, therefore, requires no filing, polishing, or removal. As with a silver contact, silver oxide is formed during arcing. It has been found that adding cadmium oxide greatly improves operation of the contact. It minimizes the tendency of one contact to weld to another and retards heavy transfer of one material to another. It also inhibits erosion. Usually, a contact with silver is serviceable as long as the total thickness worn away is only about 0.015 to 0.030 inch.

Severe pitting or burning of a silver contact is another matter. It may require some filing (with a fine file or with fine sandpaper, No. 00). Filing will remove raised places on surfaces that prevent intimate and overall closure of the contact surfaces. If necessary, wipe with a CLEAN cloth moistened with INHIBITED methyl chloroform solvent. Be certain to provide VERY LIBERAL ventilation by exhaust fans or with portable blowers. Remove all DEADLY and TOXIC fumes of the solvent.

When cleaning and dressing copper contacts, maintain the original shape of each contact surface. Remove as little copper metal as possible. Inspect and wipe the copper contact surfaces for removal of the black copper-oxide film. In extreme cases, dress and clean only with fine (No. 00) sandpaper to prevent scratching the surfaces. NEVER use emery cloth or emery paper. Because this copper-oxide film is a partial insulator, follow

the sanding procedure discussed in the previous paragraph.

Calibration problems on CBs should be handled following Chapter 300 of *Naval Ships' Technical Manual.*

The function of arcing contacts is not necessarily impaired by surface roughness. Remove very rough spots with a fine file. Replace arcing contacts when they have been burned severely and cannot be properly adjusted. Make a contact impression. Check the spring pressure following the manufacturer's instructions. If information on the correct contact pressure is not available, check the contact pressure with that of similar contacts. When the force is less than the designed value, you may have to replace the contacts if they are worn down. You may have to replace the springs. Always replace contacts in sets, not singly, and replace contact screws at the same time. Do not use emery paper or emery cloth to clean contacts. Do not clean contacts when the equipment is energized.

Clean all surfaces of the CB mechanism, particularly the insulation surfaces, with a dry cloth or air hose. Before directing the air on the breaker, be certain (1) the water is blown out of the hose, (2) the air is dry, and (3) the pressure is not over 30 psi. Check the pins, bearings, latches, and all contact and mechanism springs for excessive wear or corrosion. Check them for evidence of overheating. Replace parts if necessary.

Slowly open and close CBs manually a few times. Be certain trip shafts, toggle linkages, latches, and all other mechanical parts operate freely and without binding. Be certain the arcing contacts make-before and break-after the main contacts. If poor alignment, sluggishness, or other abnormal conditions are noted, adjust following the manufacturer's instructions for the particular CB.

Oil-piston overcurrent tripping devices (grade B timers) are sealed mechanisms. They normally do not require any attention. When oil-film (dashpot) overcurrent tripping devices are used, remove the oil every 6 months. Clean the interior of the oil chambers with kerosene and refill with new oil. Be certain the dashpot is free of dirt. Dirt can destroy the time-delay effect. Make sure the tripping device is clean, operates freely, and has enough travel to trip the breaker. Do not change the air gap setting of the moving armature. This would alter the calibration of the tripping device. Lubricate the bearing points and bearing surfaces (including latches) with a drop or two of light machine oil. Wipe off any excess oil.

Before returning a CB to service, inspect all mechanical and electrical connections. These include mounting bolts and screws, drawout disconnect devices, and control wiring. Tighten where necessary. Give the breaker a final cleaning with a cloth or compressed air. Operate manually to be certain all moving parts function freely. Check the insulation resistance.

Keep the sealing surfaces of CB contactor and relay magnets clean and free from rust. Rust on the sealing surface decreases the contact force. This may result in overheating of the contact tips. Loud humming or chattering will often warn of this condition. A light machine oil wiped sparingly on the sealing surfaces of the contactor magnet will aid in preventing rust.

Always use oil sparingly on CBs, contactors, motor controllers, relays, and other control equipment. Do not use it at all unless called for in the manufacturer's instructions or unless oil holes are provided. If working surfaces or bearings show signs of rust, disassemble the device and carefully clean the rusted surfaces. Wipe light oil on sparingly to prevent further rusting. Oil has a tendency to accumulate dust and grit. This will cause improper operation of the device, mainly if the device is delicately balanced.

Clean arc chutes or boxes by scraping with a file if wiping with a cloth is not enough. Replace or provide new linings when they are broken or burned too deeply. Be certain arc chutes are securely fastened. Be sure there is enough clearance to prevent interference when the switch or contact is opened or closed.

Replace shunts and flexible connectors, which are flexed by the motion of moving parts, when worn, broken, or frayed.

Regularly test the CBs by testing them on how they are intended to function. For manually operated CBs, simply open and close the breaker to check the mechanical operation. To check the mechanical operation and the control wiring, test electrically operated circuit breakers by the operating switch or control. Exercise care not to disrupt any electric power supply that is vital to the operation of the ship. Also, be careful not to

endanger personnel by inadvertently starting motors and energizing equipment under repair.

POWER DISTRIBUTION

Many components of the 60-Hz distribution system are located throughout the ship to provide isolation, switching, and distribution. These components include power panels, lighting load center panels, transformers, ABTs, and manual bus transfers (MBTs). This equipment routes power from the switchboard to the loads such as motors, lighting, power supplies, and electronics. Some equipment protects the distribution system from casualties in the loads; other equipment transforms and switches the power to send it to the load. In the following sections, we will discuss these components and the protective features they add to the entire distribution system.

Automatic Bus Transfers

An ABT is an electromechanical device that automatically switches power sources from normal to alternate if the normal source fails. ABTs are installed in the line of most of the vital equipment on the ship. The normal and alternate sources of power for an ABT are fed from two independent sources of power. They are never fed from two sources that originate from the same switchboard. Figure 12-23 is a line diagram of a typical vital circuit from the switchboard to the load. ABTs are also used on lighting circuits for lighting in vital areas. ABTs may be 450-volt a.c. or 115-volt a.c. We will discuss the 115-volt a.c. A2 type.

The A2 ABT unit is designed to handle smaller loads. It operates on 120-volt 60-Hz circuits. This

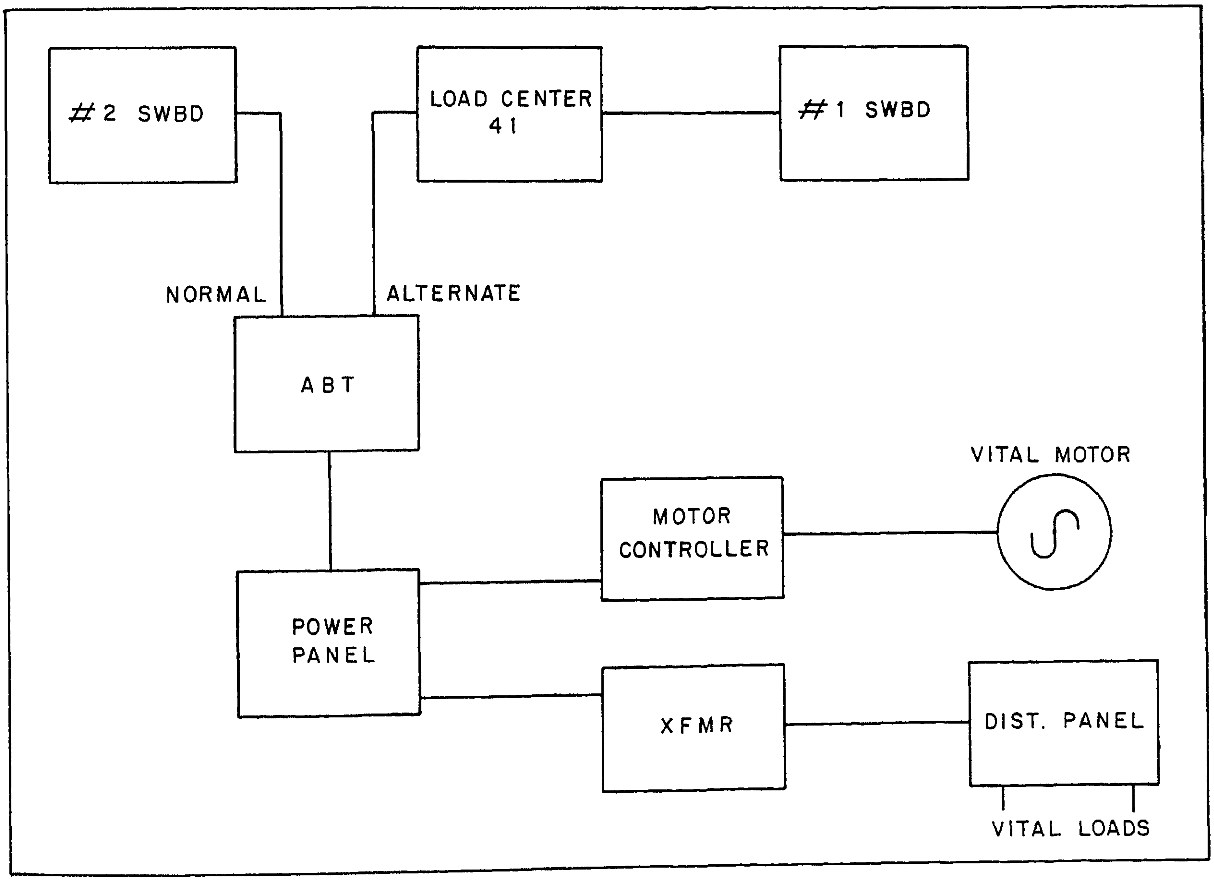


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Figure 12-23.—Typical 60-Hz vital circuit using the ABT.

unit (figure 12-24) may be used on single- or 3-phase circuits. For purposes of explanation the 3-phase unit will be discussed.

The A2 ABT is designed to transfer automatically from normal to alternate supply. It does this upon a decrease in voltage to within the 81/69-volt range across any two of its three phases. Upon restoration of the voltage to the range of 98/109 volts, the unit is adjusted to retransfer to the normal source of supply. An intentional time delay is included in the circuitry of from 0.3 to 0.5 seconds for both transfer and retransfer. This allows for surges in line voltage and short duration losses in power.

The A2 unit shown in figure 12-25 is equipped for manual operation. This is done by placing the control disconnect in the manual position and operating the manual handle.

Automatic operation is done when the normal supply voltage drops to the dropout range and relays 1V, 2V, and 3V drop out. Contact 1 Val opens disconnecting relay SE. After a time delay

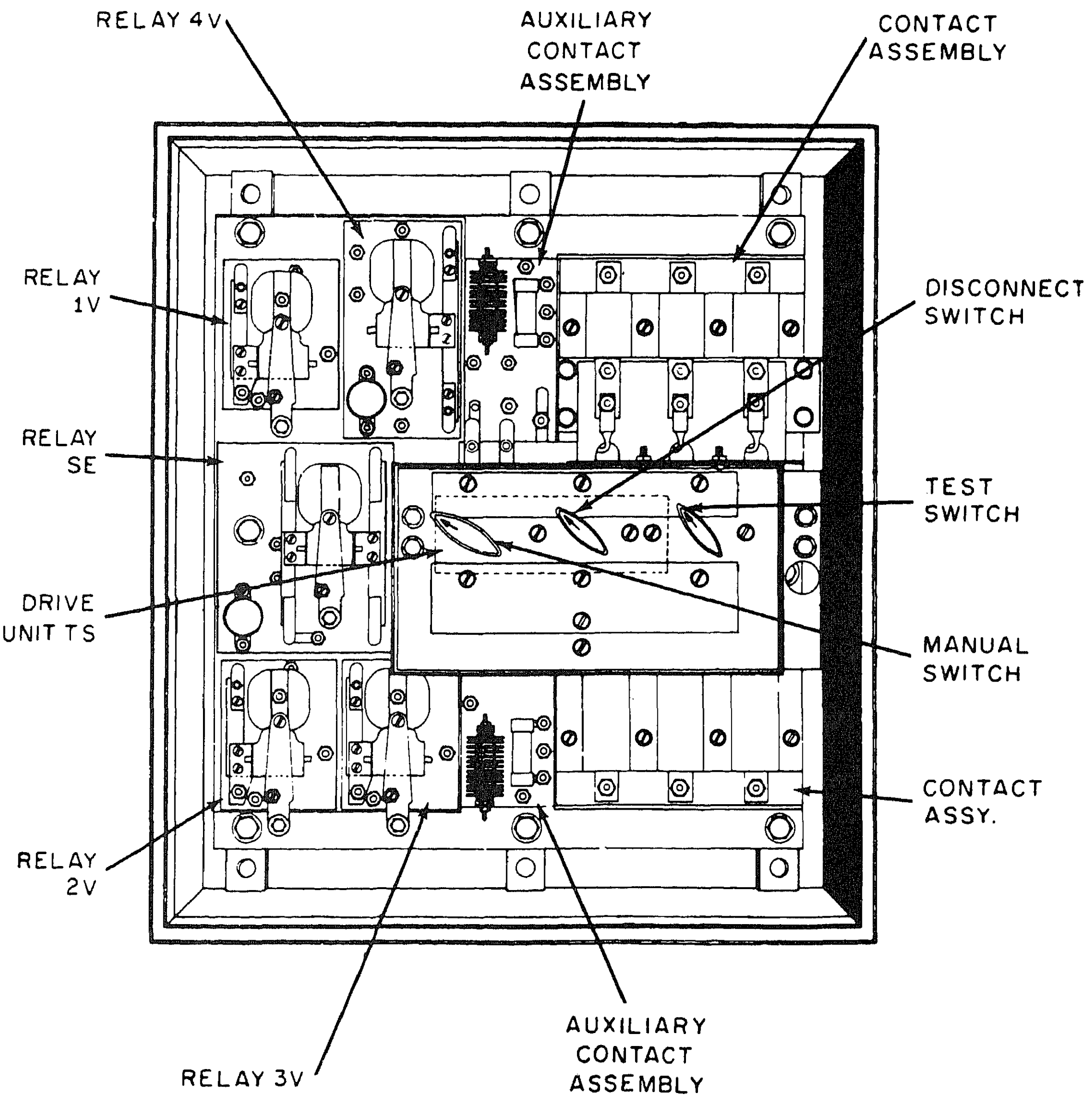

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Figure 12-24.—View of an A2 ABT with cover removed.

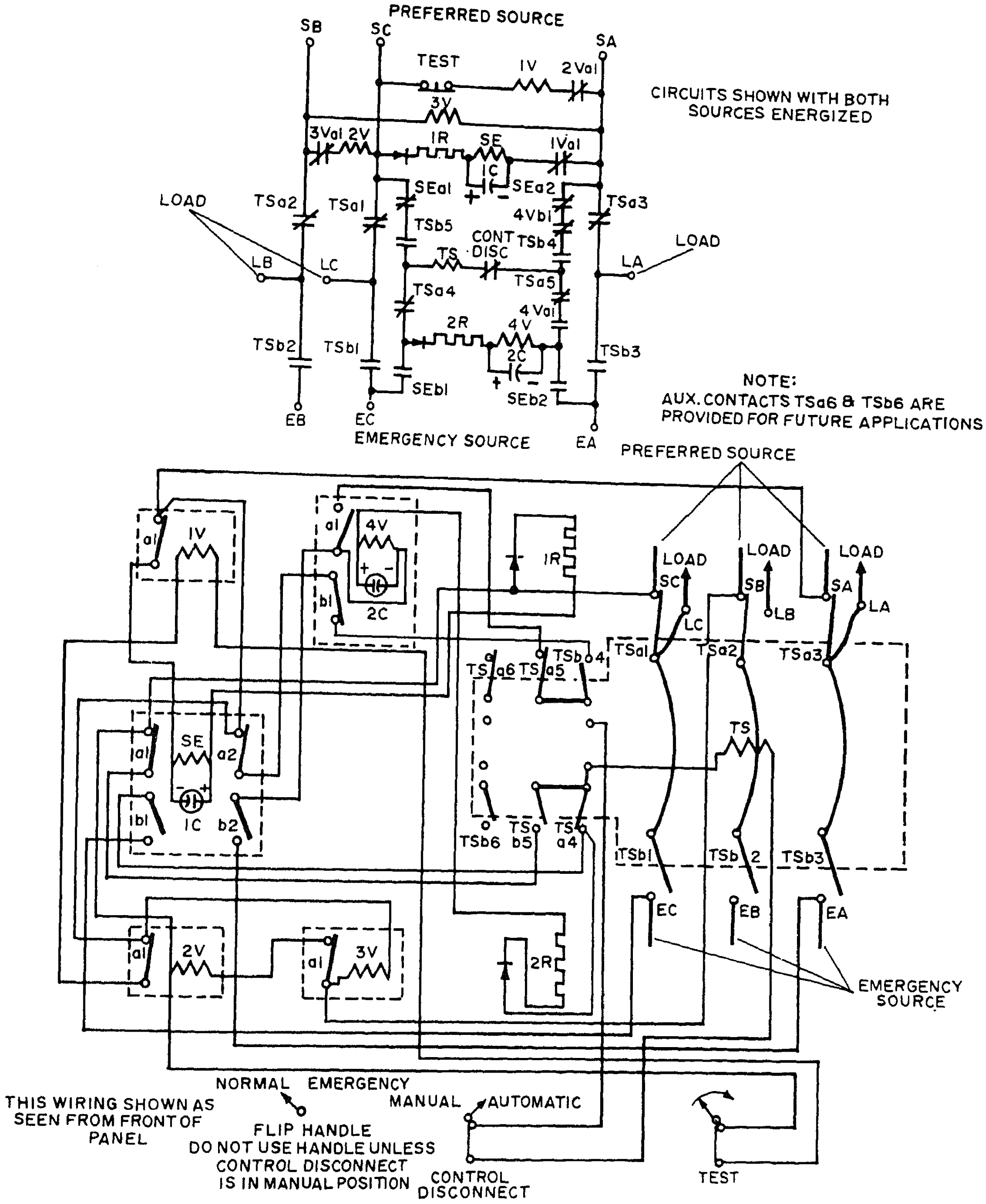

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Figure 12-25.—Schematic and wiring diagram of an A2 ABT.

of from 0.3 to 0.5 seconds, relay SE opens. It closes its SEb1 and SEb2 contacts and energizing relay 4V from the emergency source. Contact 4 Val, in closing, connects the emergency source to coil TS of the transfer switch. It, in turn, operates, transferring the load to the emergency source.

Presently, contacts TSa4 and TSa5 open, disconnecting coil TS from its operating circuit. TS is now held in the operated condition mechanically. The transfer is now complete to the emergency supply.

Upon restoration of the normal power to the selected range, the retransfer is begun by the energizing of relays 1V, 2V, and 3V. They close, energizing relay SE. Contacts SEb1 and SEb2 now open, disconnecting relay 4V from the emergency source. After the time delay, relay 4V opens, closing its 4Vb1 contact and completing the normal supply circuit to the transfer switch coil, TS. It again operates, transferring the load back to the normal supply. Presently the transfer coil contacts TSb4 and TSb5 open, disconnecting the coil from the circuit. The coil is again mechanically held. The retransfer is now complete.

Care must be exercised when testing the ABT units to ensure they do not include in their load vital and sensitive electronic circuitry that will be adversely affected by the loss and almost instant return of power. You must ensure all other groups are adequately informed of power supply system tests to be performed.

Manual Bus Transfers

The MBTs are devices located within power panels that enable manual shifting from normal to alternate power. The MBTs are used on loads that are vital but do not require automatic recovery upon loss of power. An example of a circuit with an MBT would be engine-room ventilation power. While it is desirable to have ventilation all the time, its loss for a short period of time would not adversely affect plant operation. When time permits, an operator can switch the MBT and restart the vent fans.

Most MBTs are built into the power panels they serve. They are constructed of two CBs with some type of mechanical interlock. Indicator lights are also provided to show if the source of power is available. The CBs are similar in construction to the breakers discussed earlier but have no trip element. The designation of MBT breakers is normally NQB-250 or NQB-101.

The mechanical interlock is usually a movable bar that prevents closure of both sources of power at the same time. NEVER TAMPER OR BYPASS THE INTERLOCK ON AN MBT. If both source breakers are closed at the same time, severe damage could result. If you are operating the electric plant in split-plant mode, you could end up paralleling the ship's load across cables and breakers rated much lower than the bus tie capacity. You could also parallel out of phase causing a class C fire. You could risk electrocution.

The following is the correct procedure for you to use when shifting an MBT from normal to alternate power.

1. Ensure the alternate power indicator lamp is lighted, indicating that power is available.

2. Open the normal power CB.

3. Shift the interlock to prevent closure of the normal power breaker and enable closure of the alternate power breaker.

4. Close the alternate power CB.

NOTE: If you are shifting MBTs while power is available on both sources, you should obtain permission from the EOOW before starting the above procedure. Failure to do so could cause loss of equipment that is on the line.

Transformers

A transformer is a device that has no moving parts. It transfers energy from one circuit to another by electromagnetic induction. The energy is always transferred without a change in frequency. Usually there are changes in voltage and current. A stepup transformer receives electrical energy at one voltage and delivers it at a higher voltage. Conversely, a stepdown transformer receives energy at one voltage and delivers it at

a lower voltage. Transformers require little care and maintenance because of their simple, rugged, and durable construction. The efficiency of transformers is high. Because of this, transformers are responsible for the more extensive use of a.c. than d.c. The conventional constant-potential transformer operates with the primary connected across a constant-potential source. It provides a secondary voltage that is substantially constant from no load to full load.

Various types of small single-phase transformers are used in electrical equipment. In many installations, transformers are used on switchboards to step down the voltage for indicating lights. Low-voltage transformers are included in some motor control panels to supply control circuits or to operate overload relays.

Instrument transformers include potential, or voltage, transformers and CTs. Instrument transformers are commonly used with a.c. instruments when high voltages or large currents are to be measured.

Electronic circuits and devices use many types of transformers. These provide necessary voltages for proper electron-tube operation, interstage coupling, signal amplification, and so forth. The physical construction of these transformers differs widely.

The power-supply transformer used in electronic circuits is a single-phase constant-potential transformer. It has one or more secondary windings, or a single secondary with several tap connections. These transformers have a low volt-ampere capacity. They are less efficient than large constant-potential power transformers. Most power-supply transformers for electronic equipment operate at a frequency of 50 to 60 Hz. Aircraft power-supply transformers operate at a frequency of 400 Hz. The higher frequencies permit a saving in size and weight of transformers and associated equipment.

The typical transformer has two windings insulated electrically from each other. These windings are wound on a common magnetic core made of laminated sheet steel. The principal parts are (1) the core, which provides a circuit of low reluctance for the magnetic flux; (2) the primary winding, which receives the energy from the a.c. source; (3) the secondary winding, which receives the energy by mutual induction from the primary and delivers it to the load, and (4) the enclosure.

When a transformer is used to step up the voltage, the low-voltage winding is the primary. Conversely, when a transformer is used to step down the voltage, the high-voltage winding is the primary. The primary is always connected to the source of the power; the secondary is always connected to the load. It is common practice to refer to the windings as the primary and secondary rather than the high-voltage and low-voltage windings. More information on the construction and installation of transformers is available in the *Electrician's Mate 3 & 2*, NAVEDTRA 10546-E1, pages 5-17 to 5-29.

Power Panels

Power panels (PPs) and lighting load center panels (LCPs) are located throughout the ship to distribute power to the ship's loads. The construction of PPs and lighting LCPs is similar; the major difference is that LCPs distribute 115-volt a.c. whereas PPs distribute 450-volt a.c. Larger panels use the AQB-101 CBs like those found in the switchboard. You may find different numbers of circuits in a panel, as few as four to as many as sixteen. Input power to a panel is connected to three bus bars. The CBs plug onto these to make a path of current flow to the load connections. Loads on PPs can include large motors, heaters, electronics, and distribution panels (DPs). The DPs distribute power to smaller loads such as smaller motors and distribution boxes (DBs). The DBs are fuse boxes that also supply smaller loads such as motor-operated valves and small heaters.

The LCPs distribute their power to lighting distribution panels (LDPs) and isolated receptacle circuits. The LDPs are small breaker panels that control individual 115-volt circuits. These may include lighting, solenoid valves, alarm circuits, control panels, and lighting distribution boxes (LDBs). The LDBs are fuse panels that supply

other 115-volt circuits. Figure 12-26 shows typical power and lighting circuits from the MBT/ABT to loads. Note that most panels have spare circuits for future growth.

Power Panel and Cable Marking

Some method must be used to locate PPs and the equipment that is fed. Also, switchboards must have markings on the breakers to identify what loads are fed. The Navy uses a standard system to identify the location and source of power for all switchboards, panels, and loads. This system uses the deck/frame/side location that identifies other shipboard components. The system is also used on cables to identify their power source.

The first part of the designation you encounter identifies the switchboard or load center that the power comes from. This could be numbers or a letter/number combination. The following is an example of some markings you may find and what the first number means.

1SB-4P-2-216-2-C

From #1 SWBD B section

41-4P-216-C

From load center 41

3SA-4P-42

From #3 SWBD A section

The second designation will tell you the voltage potential and the use of the power. The most common voltages encountered are 115 volts, designated by a number 1, and 450 volts, designated by number 4. The number is actually the range the voltage falls into such as

- 100 to 199—1
- 200 to 299—2
- 300 to 399—3
- 400 to 499—4

The letter part of the designation indicates the use of the power. The most common ones are

K —Control, power plant, and ship

C —Interior communications

EL —Emergency lighting

L —Lighting

CP —Casualty power

P —Ship's service power

WP—Weapon's power

Other letters and symbols are used with these basic letters to form the complete cable designation. This gives the cable's source, service, and designation. Typical markings for power systems cables from a generator to a load and the meanings of the symbols are as follows:

1. Generator cables: 2SG-4P-2S

   2SG—Fed from SS generator No. 2

   4P—450-volt power cable

   2S—Supplying SS switchgear group No. 2

2. Bus feeder: 2S-4P-31

   2S—Fed from SS switchgear group No. 2

   4P—450-volt power cable

   31—Supplying load center switchboard No. 31

3. Feeder: 31-4P-(3-125-2)

   31—Fed from load center switchboard No. 31

   4P—450-volt power cable

   (3-125-2)—Supplying power distribution panel located on third deck, frame 125, port side

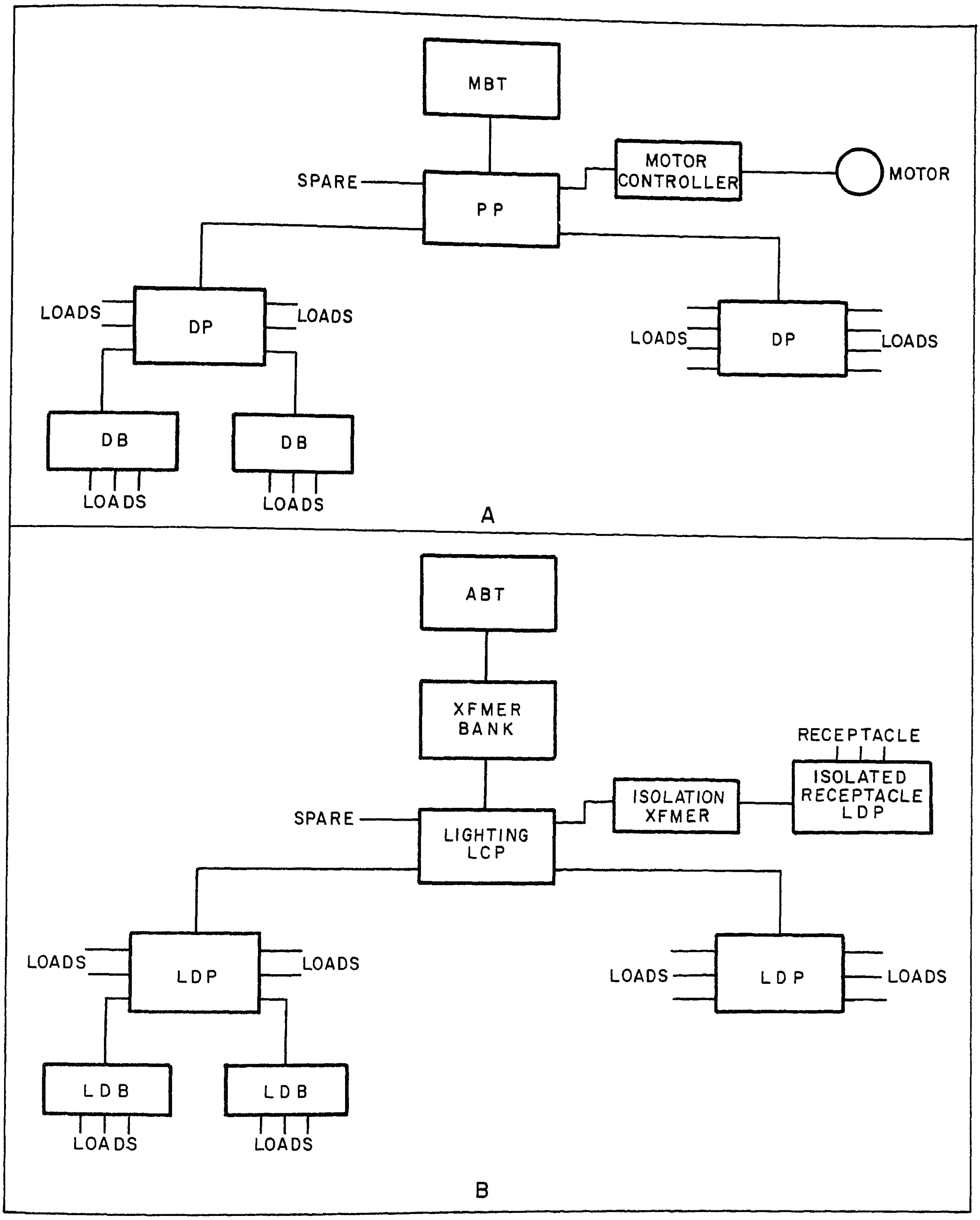

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Figure 12-26.—(A) Typical power panel distribution circuit (B) Typical lighting circuit.

4. Main: (3-125-2)-4P-C

   (3-125-2)—Fed from power distribution panel located on third deck, frame 125, port side

   4P—450-volt power cable

   C—Indicates this is the third cable from the panel, fed by breaker C

5. Submain: (3-125-2)-1P-C1

   (3-125-2)—Fed from power distribution panel located on third deck, frame 125, port side

   1P—120-volt power cable

   C1—Indicates first cable fed (through a transformer) by the main listed just above

6. Branch: (3-125-2)-1P-C1B

   (3-125-2)—Fed from power distribution panel located on third deck, frame 125, port side

   1P—120-volt power cable

   C1B—Indicates second cable fed by the submain listed just above

7. Subbranch: (3-125-2)-1P-C1B2

   (3-125-2)—Fed from power distribution panel on third deck, frame 125, port side

   1P—120-volt power cable

   C1B2—Indicates second cable fed by the branch listed just above

MOTOR CONTROLLERS

Controllers are commonly used for starting large motors aboard ship to reduce the amounts of current they require when started. The amounts are normally several times greater than the amounts the same large motors use while running. If these controllers are not used for starting, the motors and the equipment they drive may be damaged. The operation of other equipment in the same distribution system may be affected adversely. A motor controller is a device or set of devices that governs the operation of the motor it is connected to. This section describes the characteristics, uses, and operating principles of shipboard motor controllers, including their relays and switches. In this section, we also discuss the techniques of troubleshooting motor controllers.

Basically, a motor controller regulates the speed of its motor and protects it from damage. The controller functions to start the motor, stop it, increase or decrease its speed, or load or unload the motor.

A MANUAL or nonautomatic controller is operated by hand directly through a mechanical system. The operator closes and opens the contacts that normally energize and de-energize the connected load. In a MAGNETIC controller these contacts are closed and opened by electromechanical devices. The devices are operated by local or remote master switches (defined later). Magnetic controllers may be semiautomatic, automatic, or full and semiautomatic. Normally, all the functions of a semiautomatic magnetic controller are governed by one or more manual master switches; those of an automatic controller are governed by one or more automatic master switches. Automatic controllers must be energized initially by a manual master switch. A full and semiautomatic controller can be operated either as an automatic or as a semiautomatic controller.

An ACROSS-THE-LINE controller throws the connected load directly across the main supply line. The motor controller may be either a manual or magnetic type. The type depends on the rated horsepower of the motor. Most squirrel cage motors can be started across the line without producing excessive line-voltage drop or mechanical shock to a motor or auxiliary. These squirrel cage motors drive pumps, compressors, fans, lathes, and other auxiliaries. Most controllers found on gas turbine ships are magnetic across-the-line controllers.

Types of Master Switches

A master switch is a device, such as a pressure or thermostatic switch, that governs the electrical operation of a motor controller. The switch can be manually or automatically actuated. Drum, selector, and pushbutton switches are examples of a manual master switch. The automatic switch functions through the effect of a physical force,

not an operator. Examples of automatic master switches include float, limit, or pressure switches. Many of these devices were covered in chapter 3.

Depending on where it is mounted, a master switch is local or remote. A local switch is mounted in the controller enclosure; a remote switch is not. Local master switches are usually operable from outside the controller.

Master switches may start a series of operations when their contacts are closed or when their contacts are opened. In a momentary contact master switch, the contact is closed (or opened) momentarily; it then returns to its original condition. In a maintaining contact master switch, the contact does not return to its original condition after closing (or opening) until again actuated. The position of a normally open or normally closed contact in a master switch is open or closed, respectively, when the switch is de-energized. The de-energized condition for a manual controller is considered the OFF position.

Overload Relays

Nearly all shipboard motor controllers provide overload protection when motor current is excessive. This protection is provided by THERMAL or MAGNETIC overload relays. Those relays disconnect the motors from their power supply. This prevents them from overheating.

Overload relays in magnetic controllers have a normally closed contact. The contact is opened by a mechanical device that is tripped by an overload current. Opening the overload relay contacts breaks the circuit through the operating coil of the main contactor. This causes the main contactor to open. Power is cut off to the motor. Overload relays in manual controllers operate mechanically to trip the main contacts and allow them to open.

Overload relays for naval shipboard use can usually be adjusted to trip at the right current. They can protect the motor if the rated tripping current of the relay does not fit the motor it is intended to protect. They can be reset after tripping so the motor can be operated again with overload protection. Some controllers feature an emergency-run button. This button enables the motor to be run without overload protection in an emergency.

THERMAL OVERLOAD RELAYS.—The thermal overload relay has a heat-sensitive element. It has an overload heater that is connected in series with the motor load circuit. When the motor current is excessive, heat from the heater causes the heat-sensitive element to open the overload relay contact. This breaks the circuit through the operating coil of the main contactor. The motor is also disconnected from the power supply. Since it takes time for parts to heat up, the thermal overload relay has an inherent time delay. This permits the motor to do maximum work at any reasonable current. It does this only as long as the motor is not being overheated. When it is, the overload relay disconnects the motor.

Coarse adjustment of the tripping current of thermal overload relays is made by changing the heater element. Fine adjustment is made in different ways, depending upon the type of overload relay. One method of fine adjustment is to change the distance between the heater and the heat-sensitive element. Increasing this distance will increase the tripping current. Another method is to change the distance a bimetal strip has to move before the overload relay contact is opened. Refer to the manufacturer's technical manual related to the equipment for details of adjustment provided.

Thermal overload relays must be compensated. They are constructed so the tripping current is unaffected by variations in the ambient (room) temperature. Different means are used for different types. Refer to the manufacturer's technical manual related to the equipment for information on compensation provided.

There are four types of thermal overload relays: solder pot, bimetal, single metal, and induction. The heat-sensitive element of a SOLDER-POT type is a cylinder inside a hollow tube. The cylinder and tube are normally held together by a film of solder. In case of an overload, the heater melts the solder (this breaks the bond between the cylinder and tube). Then the tripping device of the relay is released. After the relay trips, the solder cools and solidifies. You can then set the relay.

In the BIMETAL type, the heat-sensitive element is a strip or coil of two different metals. They are fused together along one side. When heated, the strip or coil deflects because one metal expands more than the other. The deflection

causes the overload relay contact to open. The heat-sensitive element of the SINGLE-METAL type is a tube around the heater. The tube lengthens when heated and opens the overload relay contact

The heater in the INDUCTION type has a coil in the motor load circuit and a copper tube inside the coil. The tube acts as the short-circuited secondary of a transformer. It is heated by the current induced in it. The heat-sensitive element is usually a bimetal strip or coil.

MAGNETIC OVERLOAD RELAYS.—The magnetic overload relay has a coil connected in series with the motor load circuit and a tripping armature or plunger. When motor current exceeds the tripping current, the armature opens the overload relay contact. Though limited in application, one type of magnetic overload relay operates instantly when the motor current exceeds the tripping current. You have to set this type at a tripping current higher than the motor starting current. If not, the relay would trip each time you try to start the motor. One use of the instantaneous magnetic overload relay is in motor controllers for reduced voltage starting. It is used when starting current peaks are less than the stalled rotor current.

A second type of magnetic overload relay is delayed a short time when motor current exceeds tripping current. This type is essentially the same as the instantaneous relay except for the time-delay device. This device is usually an oil dashpot with a piston attached to the tripping armature of the relay. Oil passes through a hole in this piston when the tripping armature is moved by an overload current. You can adjust the size of the hole to change the speed at which the piston moves for a given pull on the tripping armature. For a given size hole, the larger the current, the faster the operation. The motor is thus allowed to carry a small overload current longer than a large overload current. You can set the relay to trip at a current well below the stalled rotor current. This is because the time delay gives the motor time to accelerate to full speed before the relay operates. By this time the current will have dropped to full load current. This is well below the relay trip setting.

In the instantaneous or time-delay magnetic overload relays, the tripping current is usually adjusted by changing the distance between the series coil and the tripping armature. More current is needed to actuate the armature when the distance is increased. Compensation for changes in ambient temperature is not needed for magnetic overload relays. They are practically unaffected by changes in temperature.

OVERLOAD RELAY RESETS.—After an overload relay has operated to stop a motor, it must be reset before the motor can be run again with overload protection. Magnetic overload relays can be reset immediately after tripping. Thermal overload relays must be allowed to cool a minute or longer before they can be reset. The form of overload reset is manual, automatic, or electric.

The manual, or hand, reset is located in the controller enclosure that contains the overload relay. This reset usually has a hand-operated rod, lever, or button that returns the relay tripping mechanism to its original position. It resets interlocks as well, so the motor can be run again with overload protection. An interlock is a mechanical or electrical device actuated by a second device to which it is connected. It governs succeeding operations of the second or other devices.

The automatic form, usually a spring- or gravity-operated device, resets the overload relay without the help of an operator. The electric reset is actuated by an electromagnet controlled by a pushbutton. This form is used when it is desired to reset an overload relay from a remote operating point.

OVERLOAD RELAYS—EMERGENCY RUN.—Motor controllers having an emergency run feature are used with auxiliaries that cannot be stopped safely in the midst of an operating cycle. With this feature, the operator of an auxiliary can keep it running with motor overloaded. It can run until a standby unit can take over, the operating cycle is completed, or the emergency passes. USE THIS FEATURE IN AN EMERGENCY ONLY. DO NOT USE IT OTHERWISE.

The common means of providing emergency run in magnetic controllers are emergency run pushbutton, reset-emergency run lever, and start-emergency run pushbutton. In each case, you

must hold the lever or pushbutton closed during the entire emergency.

Figure 12-27 is a schematic diagram of a controller. It shows a separate EMERGENCY RUN pushbutton with normally open contacts in parallel with the normally closed contact of the overload relay. (A schematic diagram uses standard symbols to show the electrical location and operating sequence of the individual elements or devices; the schematic does not indicate their relative physical location.) For emergency run operation, hold down this pushbutton. Press the START button to start the motor. You cannot stop the motor by opening the overload relay contact.

A RESET-EMERGENCY RUN lever is shown in figure 12-28. As long as the lever is held down, the overload relay contact is closed. You must momentarily close the START button to start the motor. Figure 12-29 shows a START-EMERGENCY RUN pushbutton. The motor starts when the button is pushed. It continues to run without overload protection as long as it is held down. For this reason, do not keep pushbuttons that are marked START-EMERGENCY

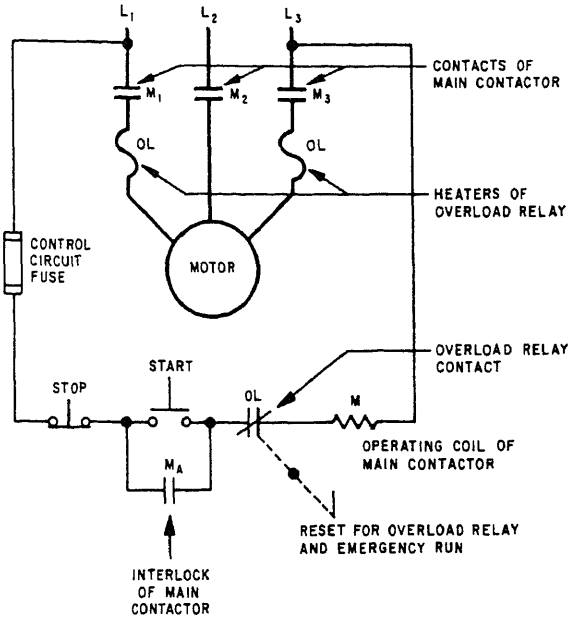

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Figure 12-28.—Schematic diagram of controller with reset-emergency run lever.

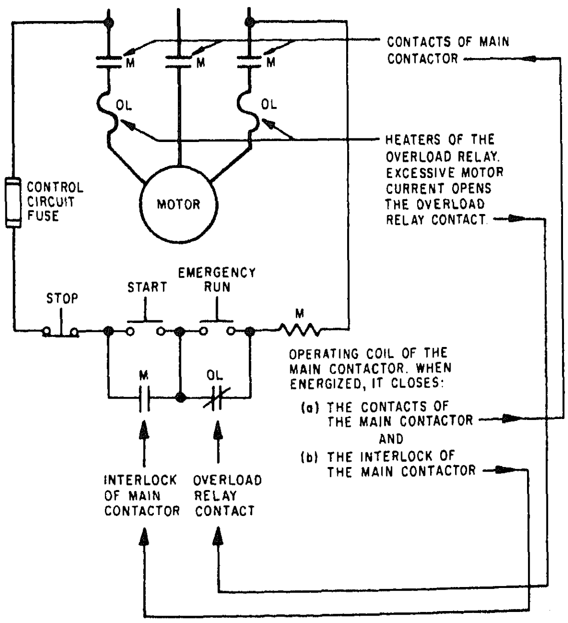

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Figure 12-27.—Schematic diagram of controller with emergency run pushbutton.

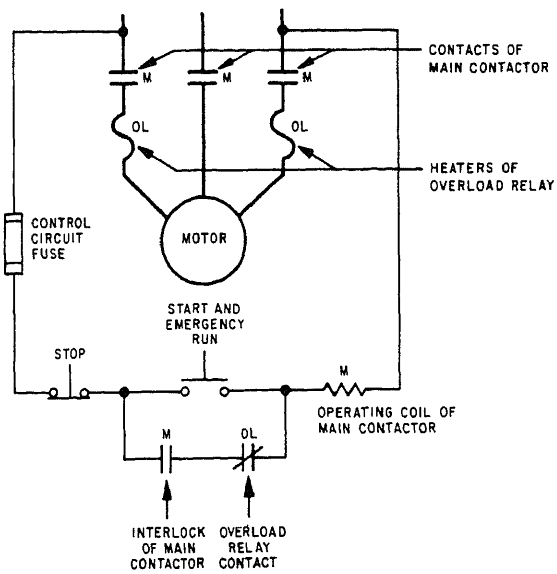

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Figure 12-29.—Schematic diagram of controller with start-emergency run pushbutton.

RUN closed for more than a second or two. An exception is if an emergency run operation is desired.

Manual controllers may also be provided with the emergency run feature. The usual means is a START-EMERGENCY RUN pushbutton or lever. The controller keeps the main contacts closed despite the tripping action of the overload relay mechanism.

SHORT CIRCUIT PROTECTION.—Overload relays and contactors are usually not designed to protect motors from currents greater than about six times normal rated current of a.c. motors. Since short-circuited currents are much higher, protection against short circuits in motor controllers is obtained through other devices. Navy practice is to protect against these short circuits with CBs placed in the power supply system. In this way, both the controller and motor are protected. The cables connected to the controller are also protected. However, sometimes short circuit protection is provided in the controller. This is done in cases where it is not otherwise provided by the power distribution system. It is also done where two or more motors are protected, but the CB rating is too high for protection of each motor separately.

Short circuit protection for control circuits is provided by fuses in the controller enclosure. The fuses are connected in control circuits. The circuits run to remote pushbuttons, pressure switches, and so forth. In general, each control wire that leaves a controller should be protected by a fuse. However, the lead may already be protected by a current limiting device located in the enclosure. Such a device could be a coil or resistor.

Low-Voltage Release

When the supply voltage is reduced or lost altogether, a low-voltage release (LVR) controller disconnects the motor from the power supply. It keeps it disconnected until the supply voltage returns to normal. Then it automatically restarts the motor. This type of controller must be equipped with a maintaining master switch.

Low-Voltage Release Effect

Most small manual across-the-line controllers have a property known as low-voltage release effect (LVRE). These controllers are switched on to start a motor. When voltage is lost, the motor stops. When voltage returns, since the switch is closed, the motor will restart. Although not truly an LVR controller, since it does restart the motor, it is known as an LVRE.

Low-Voltage Protection

With low-voltage protection (LVP), when the supply voltage is reduced or lost, you must restart the controller manually. The master switch is usually a momentary switch.

Magnetic Across-the-Line Controllers

A typical 3-phase across-the-line controller is shown in figure 12-30. Figure 12-31 shows a small cubical contactor for a 5-hp motor. All are similar in appearance but vary in size. An elementary or

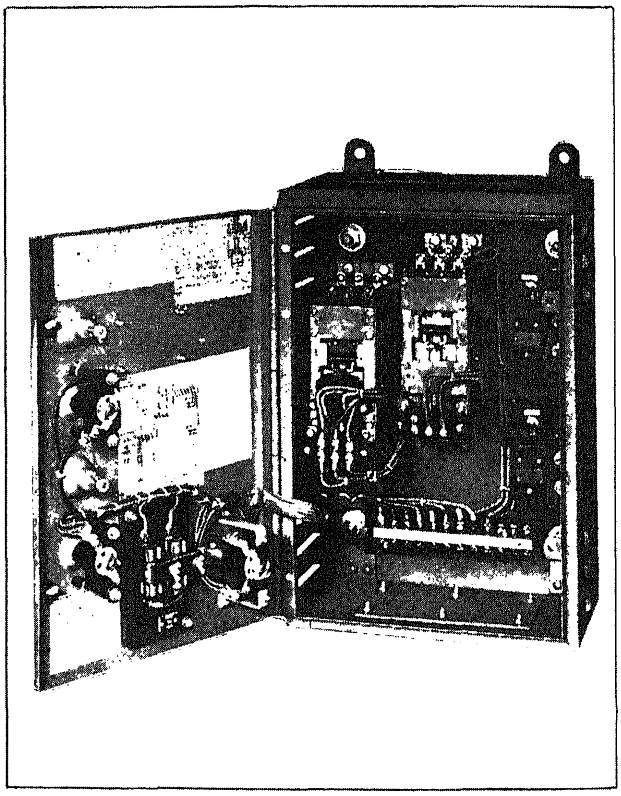

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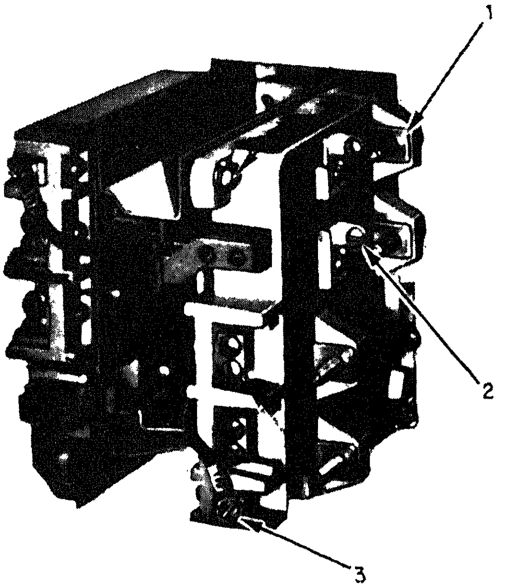
Figure 12-30.—Across-the-line 3-phase controller.



1. **Main contact terminals**
2. **Auxiliary contact terminals**
3. **Coil terminals**

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Figure 12-31.—Contactor for a 5-hp motor.

schematic diagram of a magnetic controller is shown in figure 12-28.

The motor is started by pushing the START button. The action completes the circuit from L_1 through the control fuse, STOP button, START button, the overload relay contacts, OL, and the contactor coil, M to L_3. When the coil is energized, it closes line contacts M_1, M_2, and M_3. This connects the full-line voltage to the motor. The line contactor auxiliary contact, M_A, also closes. It completes a holding circuit for energizing the coil circuit after the START pushbutton has been released.

The motor will continue to run until the contactor coil is de-energized. It can be de-energized by the STOP pushbutton, failure of the line voltage, or tripping of the overload relay, OL.

Speed Control

When operating an a.c. motor at different speeds, use a controller with a circuit as shown in figure 12-32.

An a.c. induction motor for two-speed operation may have a single winding or two separate windings. One is for each speed. Figure 12-32 is a schematic diagram of the a.c. controller for a two-speed, two-winding induction motor. The motor slow winding is connected to terminals T_1, T_2, and T_3. The motor fast winding is connected to terminals T_{11}, T_{12}, and T_{13}. Overload protection is provided by the LOL coils and contacts for the slow winding and the HOL contacts and coils for the fast winding. The LOL and HOL contacts are connected in series in the maintaining circuit. They must both be closed before the motor will operate on either speed.

The control pushbuttons are of the momentary contact type. Pressing the high-speed pushbutton closes the high-speed contactor by energizing coil HM. This coil remains energized after the pushbutton is released by holding contacts HA. The coil, HM, also closes main line

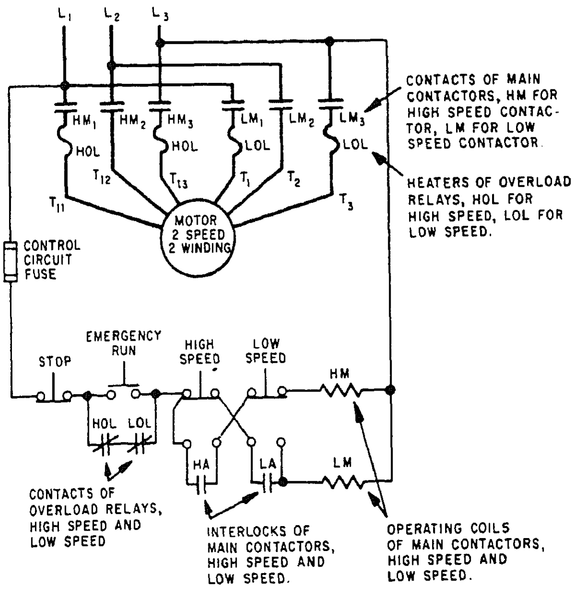

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Figure 12-32.—Schematic diagram of a two-speed a.c. controller.

contacts HM_1, HM_2, and HM_3. They apply full-line voltage to the motor high-speed winding. The motor will then run at high speed until coil HM is de-energized.

Pressing the low-speed pushbutton closes the low-speed contactor by energizing coil LM. The coil remains energized after the button is released by holding contacts LA. The coil, LM, also closes main line contacts LM_1, LM_2, and LM_3. They apply full-line voltage to the motor low-speed winding. The motor will then run at low speed until coil LM is de-energized. The LM and HM contactors are mechanically interlocked. This prevents both being closed at the same time.

Controller Troubleshooting

Although the Navy maintains a policy of preventive maintenance, sometimes trouble is unavoidable. In general, when a controller fails to operate or trouble occurs, you can find the trouble by using (for heat, smoke, or smell of burning) the sense of feel, sight, or smell. However, at other times, finding the trouble involves more detailed actions.

Troubles tend to gather around mechanical moving parts. Problems also occur where electrical systems are interrupted by the making and breaking of contacts. Center your attention in these areas. See table 12-4 for a list of common troubles, their causes, and corrective actions.

Table 12-4.—Motor Controller Troubleshooting Chart

Contacts		
Trouble	**Probable cause**	**Remedy**
Contact chatter	Poor contact in control relay	Clean relay contact.
	Broken shading coil	Replace.
	Excessive jogging	Caution operator to avoid excessive jogging.
Overheated contact tips	Dirty contact tips	Clean and dress, if necessary, in accordance with chapter 300 or manufacturer's instructions.
	Sustained overloads	Find and remedy the cause of the overloads.
	Insufficient tip pressure	Clean and adjust.
	Loose connections	Clean and tighten.
Weak tip pressure	Wear allowance gone	Replace contacts and adjust.
	Poor tip adjustment	Adjust "gap" and "wipe."
	Low voltage which prevents magnet sealing	Correct voltage condition.
Short tip life	Excessive filing or dressing	Follow manufacturer's instructions.
	Excessive jogging	Instruct operator in correct operation.
Welding or fusing	Abnormal starting currents	Operate manual controllers slower. Check automatic controllers for correct starting resistors and proper functioning of timing devices or accelerating relays.
	Rapid jogging	Instruct operator in correct operation.
	Short circuit currents on contacts	Find and remedy causes of short circuits. Check feeder fuses for proper size and replace, if necessary.
Failure of the flexible conductors between fixed and moving parts of contactor	Improper installation	See manufactuer's instructions.
	Worn out mechanically by large number of operations	Replace.
	Moisture or corrosive atmosphere	Replace with flexible conductors suitable for application.
	Burned by arcing or overheating from loose, oxidized, or corroded connections	Clean and tighten connections.

Table 12-4.—Motor Controller Troubleshooting Chart—Continued

Coils

Trouble	**Probable cause**	**Remedy**
Coil failure:		
(a) Not overheated	Moisture, corrosive atmosphere	Use correctly insulated coils.
	Mechanical damage	Avoid handling coils by the leads.
	Vibration or shock damage	Secure coils properly.
(b) Overheated	Overvoltage or high ambient temperature	Check current and application.
	Wrong coil	Use only the manufacturer's recommended coil.
	Too frequent use, or rapid jogging	Use correct operating procedure.
	Undervoltage, failure of magnet to seal in	Check circuit and correct cause of low voltage.
	Used above current rating	Install correct coil for the application.
	Loose connections to coil, or corrosion or oxidation of connection surfaces	Clean and tighten connection.
	Improper installation	See manufacturer's instructions.

Overload relays

Trouble	**Probable cause**	**Remedy**
Magnetic, instantaneous type:		
High or low trip	Wrong coil	Install correct coil.
	Mechanical binding, dirt, corrosion, etc.	Clean with approved solvent, adjust.
	Shorted turns (high trip)	Test coil, and replace if defective.
	Assembled incorrectly	Refer to manufacturer's instructions for correct assembly.
	Wrong calibration	Replace.
Magnetic, inverse time delay type:		
Slow trip	Fluid dirty, gummy, etc.	Change fluid and fill to correct level.
	Mechanical binding, corrosion, etc.	Clean with approved solvent, adjust.
	Worn or broken parts	Replace and adjust.
	Fluid too low	Drain and refill to correct level.
Thermal type:		
Failure to trip	Wrong size heater	Install correct size.
	Mechanical binding, dirt, corrosion, etc.	Clean with approved solvent and adjust.
	Relay damaged by a previous short circuit	Replace.
Trips at too low temperature	Wrong size heater	Install correct size.
	Assembled incorrectly	See technical manual for correct assembly.
	Wrong cailibration	Replace.
Failure to reset	Broken mechanism or worn parts	Replace.
	Corrosion, dirt, etc.	Clean and adjust.
Burning and welding of control contacts	Short circuits in control circuits with fuses that are too large	Correct causes of short circuits and make sure that fuses are right size.
Turning relays, flux decay type:		
Too short time	Dirt in air gap	Clean.
	Shim too thick	Replace with thinner shim.
	Too much spring or tip pressure	Adjust as per technical manual.
	Misalignment	Correct alignment, and remedy cause of misalignment.

Table 12-4.—Motor Controller Troubleshooting Chart—Continued

Overload relays—Continued

Trouble	Probable cause	Remedy
Too long time	Shim worn too thin	Replace with thicker shim.
	Weak spring and tip pressure	Adjust as per technical manual.
	Gummy substance on magnet face or mechanical binding	Clean with approved solvent and adjust.

Magnets and mechanical parts

Trouble	Probable cause	Remedy
Worn or broken parts	Heavy slamming caused by overvoltage or wrong coil	Replace part and correct cause.
	Chattering caused by broken shading coil or poor contact in control circuit	
	Excessive jogging	
	Mechanical abuse	
Noisy magnet	Broken shading coil	Replace.
	Magnet faces not true, result of mounting strain	Correct mounting.
	Dirt or rust on magnet face	Clean.
	Low voltage	Check system voltage and correct if wrong.
	Improper adjustment, magnet overloaded	Check and adjust according to manufacturer's instructions.
Broken shading coil	Heavy slamming caused by overvoltage, magnet underloaded, weak tip pressure	Replace coil and correct the cause.
Failure to drop out	Gummy substances on magnet faces	Clean with approved solvent.
	Worn bearings	Replace.
	Nonmagnetic gap in magnet circuit	Replace magnet.
	Voltage not removed	Check coil voltage.
	Not enough mechanical load on magnet, improper adjustment	Adjust as per manufactuer's instructions.

When a motor-controller system has failed and pressing the START button will not start the system, then press the overload relay reset pushbuttons. Again attempt to start the motor. Observe what happens. The system may start and operation is restored; you may hear the controller power contacts close but the motor will not start, the system may be dead. If you hear the power contacts close, then the POWER circuit needs to be checked. If the system remains dead, then the CONTROL circuit will have to be checked. An example of troubleshooting a motor-controller electrical system is given in a sequence of steps. These may be used in locating a fault (figure 12-33). First, we will start by analyzing the power circuit.

POWER CIRCUIT ANALYSIS.—When no visual signs of failure can be located and an electrical failure is indicated in the power circuit, first check the line voltage and fuses as shown in figure 12-33. Place the voltmeter probes on the hot side of the line fuses as shown at position *A*. A line voltage reading tells you that your voltmeter is operational. It tells you that you have voltage to the source side of the line fuses L1-L2. You may also check between L1-L3 and L2-L3. To check the fuse in line 1 (L1), place the voltmeter across the line fuse as shown at position *B* between L1-L2. A voltage reading shows a good fuse in L1. Likewise, check the other two fuses between L1-L3 and L2-L3. A no-voltage reading would show a faulty fuse.

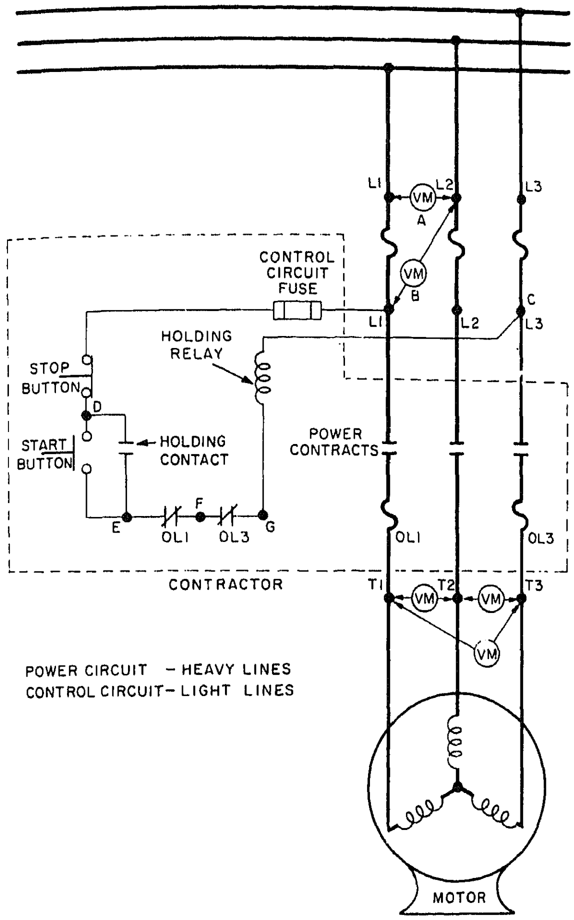

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Figure 12-33.—Troubleshooting a 3-phase magnetic controller.

If the line fuses check good, then check the voltage between terminals T1-T2, T2-T3, and T1-T3. The controller is faulty if there are no voltmeter readings on all three of the terminal pairs. You would then proceed to check the power contacts, overloads, and lead connections within the controller. However, if there is voltage at all three terminals, then the trouble is either in the motor or lines leading to the motor.

CONTROL CIRCUIT ANALYSIS.— Suppose the overload reset buttons have been reset and the START switch closed. If the power contacts do not close, then check the control circuit. A testing procedure follows.

1. Check for voltage at the controller at lines L1, L2, L3.
2. Place the voltmeter probes at points *C* and *D* (figure 12-33). You should have a voltage reading when the STOP switch is closed. You should have a no-voltage reading when the STOP switch is open. The conditions would indicate a good STOP switch.
3. Next, check the voltage between points *C* and *E*. The START switch is good if you get a no-voltage reading when the START switch is open. The START switch is also good if you get a voltage reading when the START switch is closed.
4. Place the voltmeter probes at points *C* and *F*. A voltage reading with the START button closed would indicate a good OL1. It would also indicate an open OL3, an open relay coil, or an open connection to line 3.
5. Place the voltmeter probes at points *C* and *G*. Close the START switch. A no-voltage reading locates the trouble in the control circuit; the OL3 is faulty.

A faulty holding relay contact is indicated under the following conditions. (1) The system operates only as long as the START pushbutton switch is held in the ON position. (2) When the switch is released, the system will shut down.

When starting a 3-phase motor, if the motor fails to start and gives a loud hum, you should stop the motor by pushing the STOP pushbutton. These symptoms usually mean that one of the phases to the motor is not energized. You can assume that the control circuit is good. This is because the main operating coil has operated and the maintaining contacts are holding the main operating contactor in. Look for trouble in the power circuit (the main contacts, overload relays, cable, and motor).

60-HERTZ SWITCHBOARDS

The SS switchboards are the interface of all control, monitoring, and distribution system

components of the 60-Hz system. Almost all the control circuits of the EPCC are tied into the switchboard for operation of the electric plant. As we have already discussed, they are the connection points for generators and loads. Although normally unmanned control stations, they can perform all operations normally conducted at the EPCC.

Most of the space inside a switchboard is taken up by bus work and breakers. Some space is devoted to the control relays and circuits used to operate the GBs, voltage regulator, governor, and monitoring devices.

SWITCHBOARD CONSTRUCTION

A switchgear group (figure 12-34) is a single section or several sections of switchboard mounted near one another. They are connected together with cabling. They are enclosed in a sheet-steel enclosure from which only handles and meters protrude. No live contacts are normally exposed on any switchboard on a gas turbine ship. The sections are identified with a number and letter designation. When discussing the entire switchgear, the designation is its number followed by the abbreviation *SG*. Each section is identified by its number followed by *S* or *SA* for the control section and *SA* or *SB* for the next sections. On the FFG-7 class, each switchboard has two sections. The *SA* is the control section; the *SB* is used for distribution breakers. On the larger gas turbine ships, the *SG* is composed of three sections. The control section is the *S* section; the distribution breakers are on the *SA* and *SB* sections.

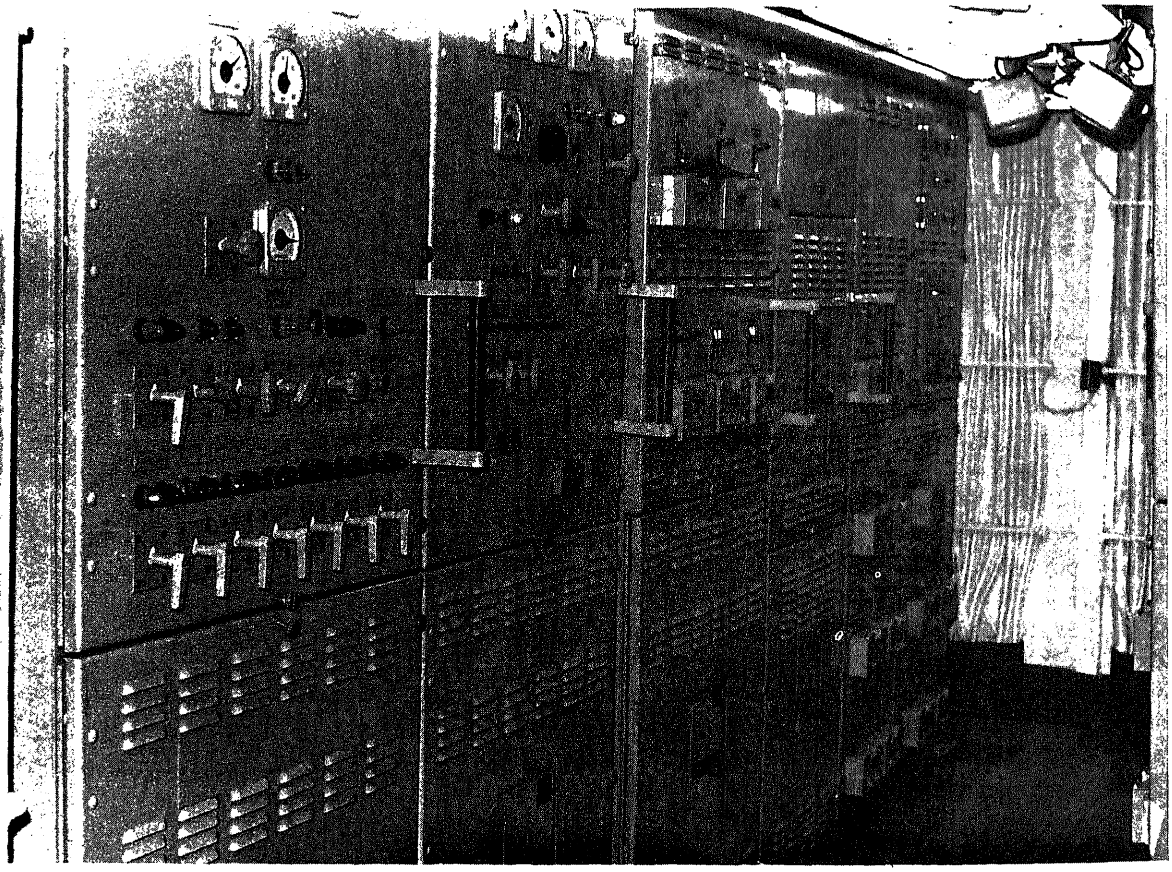

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Figure 12-34.—Switchgear group.

Example:

FFG-7

No. 1 SSDG feeds the 1SG group composed of 1SA and 1SB.

DD, DDG, CG

No. 2 SSGTG feeds the 2SG group composed of 2S, 2SA, and 2SB.

Figure 12-34 shows the 2S and 2SB sections of a CG-47 switchboard. (2SA is not visible.)

Switchboard bus bars (figure 12-35) are heavy, rugged metal bars. They distribute the power within the switchboard. They are used because they can carry the large amount of current found in the switchboard.

Current between switchboard sections is also very high. Large cables are used to connect these sections. Since there are no CBs between sections, you have to use some device to isolate a section

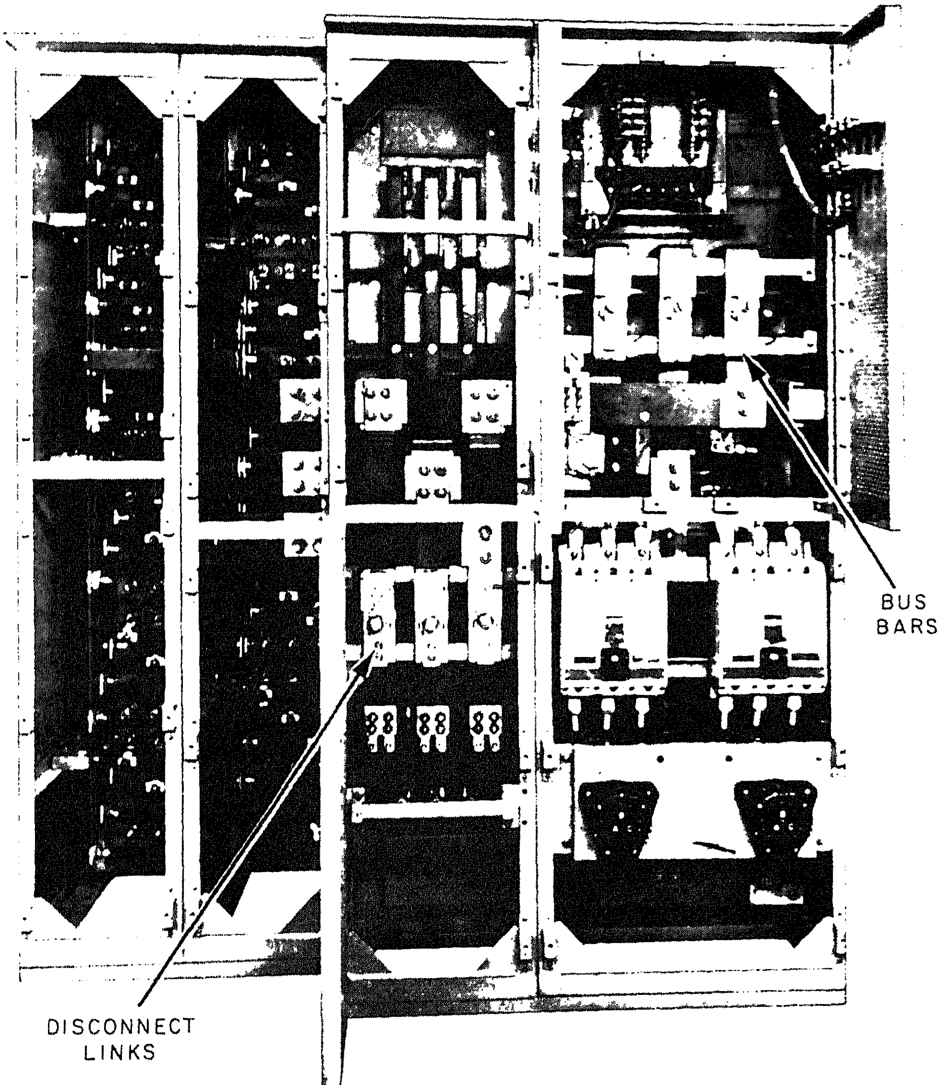

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Figure 12-35.—Rear view of a switchboard showing bus bars.

after a casualty. Disconnect links (figure 12-36) are used for this purpose. These devices are connected to the bus bars and normally carry the entire bus current. One disconnect link is used on each phase. They are mounted on both ends of the interconnecting cable. NOTE: NEVER OPEN OR CLOSE DISCONNECT LINKS ON A LIVE SWITCHBOARD. If you have to isolate a switchboard section, first secure power to the entire switchboard. Do this by opening the GB and the BTBs on switchboards feeding the damaged switchgear group. You should not operate the disconnect links until you have secured all power and tested the bus bars for voltage. Only experienced technicians familiar with switchboards should operate disconnect links. Operate disconnect links only with the approval of the engineer officer.

CONTROL AND MONITORING

Operation of 60-Hz switchboards is always done using the EOSS. Although each class ship has items peculiar only to that class, operation of switchboards is fairly common for all 60-Hz systems. We will discuss the operation of the DD-963 class as an explanation of basic operational principles. Before operating any 60-Hz system, you will undergo extensive shipboard training using PQS to qualify as an electrical watch stander.

GTGS Controls

Figure 12-37 shows a panel layout of the devices covered in this section. Please follow

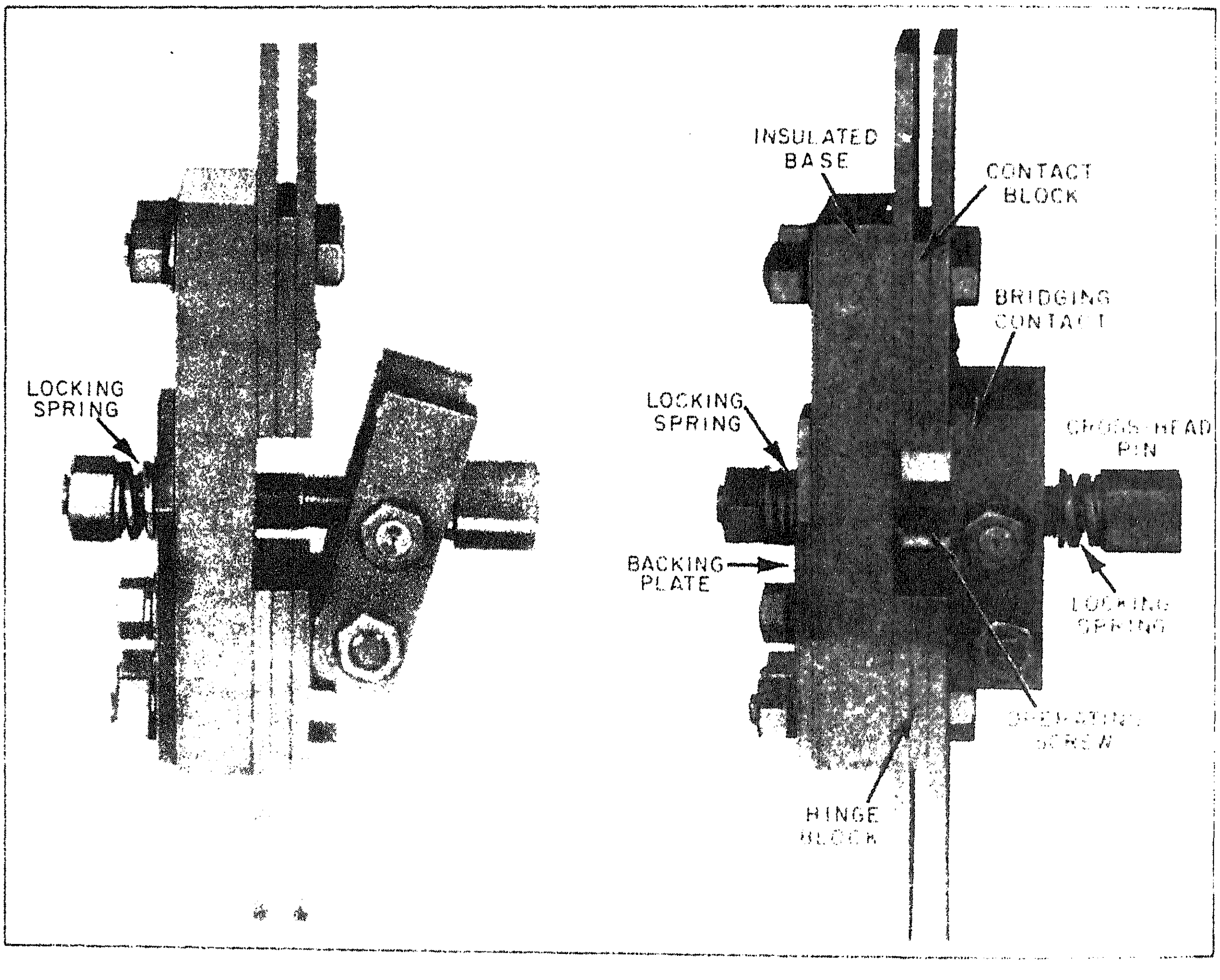

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Figure 12-36.—Disconnect links.

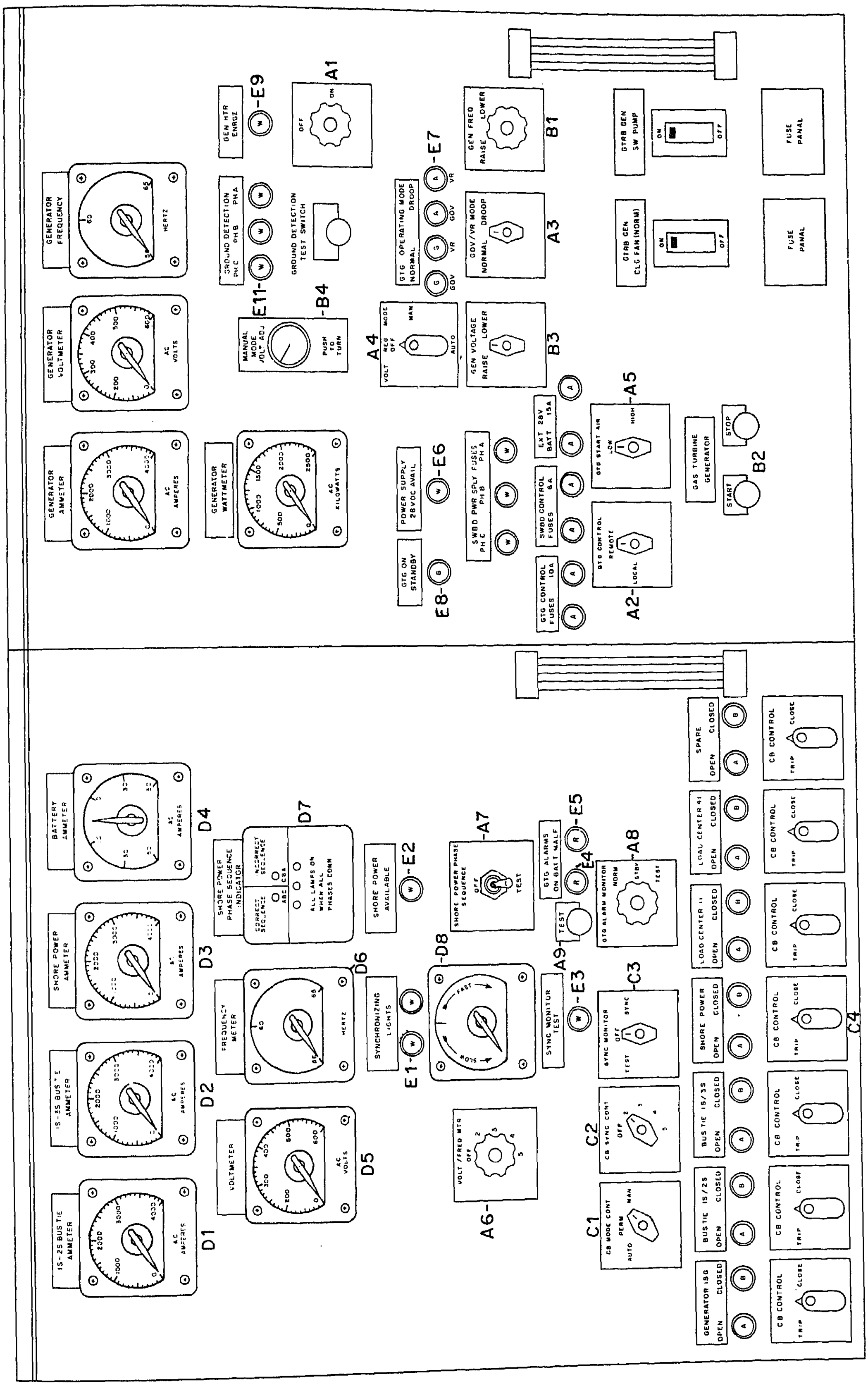

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Figure 12-37.—Control section of a switchboard on a DD-963 class ship.

figure 12-37 as we discuss the selector switches, control devices, CB control devices, instrument monitoring meters, and indicating lights. The parenthetical letters and numbers are indicated on figure 12-37.

SELECTOR SWITCHES.—The following are descriptions of the different selector switches.

(A1) GEN HTR ENRGZ—OFF/ON. Brings 115-volt a.c. lighting power to the space heater control and power circuit.

(A2) GTG CONTROL—LOCAL/REMOTE. When in LOCAL, permits stopping of GTGS and closing of selected electrical operated breakers in the manual mode. With the LOCOP switch in its REMOTE position and the GTG CONTROL switch in LOCAL, you can start the GTGS from the switchboard.

When in REMOTE, the GTGS cannot be started or stopped from the switchboard. Both manual and automatic control of the breakers is passed on to EPCE in CCS.

(A3) GOV/VR MODE—NORMAL/DROOP. Selects mode of governor and voltage regulator. In droop mode both generator voltage and generator speed lower with increasing load.

(A4) VOLT REG MODE—OFF/MAN/AUTO.

OFF—Removes generator bus power and PMA power from regulator exciter circuits.

MAN—Connects manual motor operated rheostat into the circuit. This energizes and controls excitation of the magnetic amplifier winding. Thus, the field rectifier output to the generator field is controlled.

AUTO—Connects the voltage regulator into the circuit with its rheostat. Disconnects manual circuits.

(A5) GTG START AIR—LOW/HIGH. Selects method of starting LP (bleed air) air or HP air. You cannot start the GTG from the switchboard on bleed air if the switchboard bus is dead.

(A6) VOLT/FREQ MTR—OFF-2-3-4. Connects frequency meter and voltmeter to the main bus or either of the two bus ties. On switchboard 1S a position 5 is added for monitoring of the shore power bus.

(A7) SHORE POWER PHASE SEQUENCE—OFF/TEST. Connects shore power phase sequence indicator to the shore power voltage. It is a toggle switch that spring returns to OFF.

(A8) GTG ALARM MONITOR—NORM/STBY/TEST. In NORM position, the GTG MALF (malfunction) light will illuminate on a summary alarm or a loss of 28-volt power supply voltage. Also the horn will sound if in local control. In STANDBY, the GTG MALF light will illuminate continuously, but the horn will not sound. In TEST, the MALF light will illuminate and the horn will sound (if in LOCAL control).

(A9) TEST—Pushbutton for testing the 28-volt power supply. Depressing the pushbutton will open the circuit to the coil of the monitor relay. The GTG ON BTRY light should illuminate. The GTG MALF light should illuminate and the horn sound. The POWER SUPPLY 28 VDC AVAIL light should extinguish during this test.

CONTROL SWITCHES AND DEVICES.—The following are descriptions of control switches and devices.

(B1) GEN FREQ—RAISE/LOWER. Provides for raising and lowering speed of the GTGS. Inoperative in AUTO CB control mode.

(B2) GAS TURBINE GENERATOR—START and STOP pushbuttons. Provides for starting and stopping of gas turbine when in the LOCAL control mode.

(B3) GEN VOLTAGE—RAISE/LOWER. Provides for raising and lowering of generator voltage. Operates manual motor-operated potentiometer when VR mode selector is in MAN position. Operates motor-operated voltage regulator setpoint potentiometer when VR mode selector is in AUTO position.

(B4) MANUAL MODE VOLT ADJ. Pressing and turning will mechanically raise or lower the manual motor-operated potentiometer. It does this regardless of the position of the VR mode selector.

CIRCUIT BREAKER CONTROL DEVICES.—The following are descriptions of CB control devices.

(C1) CB MODE CONT—AUTO/PERM/MAN. In the MAN position, it allows any breaker selected by the CB SYNC CONT switch to be closed by its respective CB CONTROL switch. It does this regardless of the phase angle differences across the breaker.

In the PERM position, the operation is the same as MAN except the Sync Monitor is connected into the circuit. The breaker cannot be closed unless the Sync Monitor is satisfied.

In the AUTO position, circuits are provided to close the GB if no voltage is on the switchboard bus, the two associated BTBs are open, and the generator frequency is above 57 Hz. This is effective only in LOCAL control. This is known as dead bus logic.

(C2) CB SYNC CONT—OFF-2-3-4. Allows closing of selected breaker by respective CB CONTROL switch. On switchboard 1S a position 5 is added for selecting the shore power breaker. Position 2 selects the GB. Positions 3 and 4 select the BTBs.

(C3) SYNC MONITOR—TEST/OFF/SYNC. TEST position is not used. SYNC position connects the synchronizing monitor into the circuit to monitor the two sides of the breaker as selected by the CB SYNC CONT switch. This switch must be in SYNC position for operation at EPCE in the manual permissive operating mode. The synchronizing monitor is a solid-state device with relay contact output. It has four plug-in modules. The frequency module prevents energizing the output relay unless the difference between the oncoming generator and the bus is less than 0.2 Hz. The voltage module prevents energizing the output relay unless the difference in voltage between the oncoming generator is within 5 percent of rated voltage. The phase angle module prevents energizing the output relay unless the phase angle between the oncoming generator and the bus is between minus 30 and zero electrical degrees. The output module responds to the outputs from the three modules. It contains the output relays.

(C4) CB CONTROL—TRIP/CLOSE. Momentarily turning to TRIP will trip the corresponding breaker. Momentarily turning a load center CB CONTROL to CLOSE will close the corresponding breaker. However, turning a CB CONTROL switch for the GB, either BTB or the shore power breaker, will close the corresponding breaker only if selected by CB SYNC CONT switch.

INSTRUMENT MONITORING.—The generator is provided with an ammeter, a voltmeter, a frequency meter, and a wattmeter. Ammeters are provided for each of the two bus ties (D1, D2), shore power (D3), and the 28-volt battery supply (D4).

(D5 and D6). A VOLTMETER and FREQUENCY METER are provided for connection through the VOLT/FREQ MTR (D6) switch to the switchboard bus, either BTB and, in case of 1SG, to the shore power bus.

(D7) A SHORE POWER PHASE SEQUENCE INDICATOR provides two functions. It indicates presence of voltage on each of three phases as well as ABC or CBA phase rotation.

(D8) CB SYNC CONT switch. The synchroscope monitors across any breaker selected by CB SYNC CONT switch. The oncoming bus is always considered to be on the side of the breaker nearest the generator. The bus or reference is considered to be on the side of the breaker farthest from the generator.

INDICATING LIGHT MONITORING.—The following are descriptions of the lights covered in this section.

(E1) The SYNCHRONIZING lights are connected into the circuits along with the synchroscope. When illuminated, they indicate out-of-phase voltages between oncoming and bus. They are dark when the two voltages are in phase.

(E2) The SHORE POWER AVAILABLE light is connected to the secondary of a control transformer whose primary is energized from the shore power bus.

(E3) The SYNC MONITOR TEST light indicates that the output relays of the synchronizing monitor are energized. It indicates that closing of the breaker selected by the CB SYNC CONT switch may be done by the proper CB CONTROL switch.

(E4) GTG ALARMS light ON/BATT is illuminated when the K30 relay is de-energized. It indicates the power supply is no longer supplying voltage.

(E5) GTG ALARMS light MALF is illuminated when the GTG summary alarm is initiated or when K30 relay is de-energized.

(E6) POWER SUPPLY 28 VDC AVAIL is illuminated when K30 relay is energized.

(E7) GTG OPERATING MODE—NORMAL GOV/VR and DROOP GOV/VR. The GOV/VR MODE switch is spring return to the point between the NORMAL and DROOP positions. Therefore, these lights are the necessary indication of the position of the latch-type relays in the static exciter voltage regulator assembly.

(E8) GTG ON STANDBY. When illuminated, indicates generator control panel ON/OFF/REMOTE selector is in REMOTE, GOV/VR in NORM, generator breaker OPEN, and CB MODE CONT in AUTO.

(E9) GEN HTR ENRGZ—Illuminated when 115-volt a.c. lighting supply voltage is applied to generator space heaters. This is through a CB on the switchboard and an interlock on the GB.

(E10) CB OPEN/CLOSE—Indicates open/close status of electrically operated breakers.

(E11) GROUND DETECTION—PH A, PH B, PH C. This system has three transformers connected Y-Y with phase lights connected across each secondary. Depressing the ground detection test switch connects the neutral of the primary windings to ground. If one of the phases is grounded, the primary of the associated transformer will be shorted, the light on the secondary of that transformer will extinguish.

The remaining lights monitor the fuses for the 450-volt, 3-phase, 60-Hz supply to the 28-volt d.c. power supply, the 24-volt d.c. external battery supply to the switchboard, the 28-volt d.c. supply from the switchboard to the generator control panel, and the 28-volt d.c. supply to the switchboard control circuits.

SWITCHBOARD OPERATION

Detailed instructions for operating and securing the electric plant distribution and control system are contained in the EOSS. Consult the current EOSS for operation. The procedures given below are FOR EXAMPLE ONLY. Operation of the electric plant is normally done at the EPCC. At this console total plant monitoring and control are provided. Under certain circumstances, you may have to start a GTGS from a switchboard. Then bring it on the line. A summary of this operation and other local procedures is presented in the following sections.

Gas Turbine Generator LOCOP

The LOCOP has the a.c. and d.c. control power switches that must be in the ON position for operation. It is mounted on the generator frame. If the engine has been standing idle more than 7 days, it must be motored (turned slowly). This provides lubricating oil to all bearings and journals before start-up. All preset checks must be performed in following the EOSS before engine control is transferred to REMOTE. Placing the ON-OFF-REMOTE switch in REMOTE transfers engine control to the switchboard control panel. The LOCOP STOP pushbutton is not disabled, and motoring control is not transferred. Two selector switches on the generator set control panel provide for local-remote transfer and selection of HP or LP starting air. With the LOCOP selector in the REMOTE position and the switchboard selector in the LOCAL position, the engine START switch on the switchboard is activated.

Starting a Gas Turbine Generator From a Switchboard

After completing preliminary checks and transferring control (following the EOSS) to the switchboards, take the following steps to start the GTGS. (You are to assume the switchboard bus is energized from another source.)

1. Close the GTRB GEN CLG FAN (NORM) and GTRB GEN S W PUMP CBs. The cooling water and module cooling air will be supplied upon engine start-up. Turn GEN HTR switch ON. NOTE: Ensure that all CB switches are ON. This enables the CB to close on command. These switches are located on the CBs.
2. Place the GTG ALARM MONITOR switch in STBY to silence the horn. (Return to NORM after lube oil pressure has built up.)
3. Position the GB MODE CONT switch to PERM. This permits closing of the CB only through the synchronizing monitor.
4. Position the CB SYNC CONT switch to OFF. This prevents the closing of the generator, shore power, or either BTB from their individual CB CONTROL switches. It also disconnects synchronizing voltages from the synchronizing monitor.
5. Position the GTG START AIR switch to LOW. If LP air is not available, select HP air.
6. Position the VOLT REG MODE switch to MAN. This allows the application of an excitation voltage to the generator field equal to the generator output (nonregulating).
7. Position the GOV/VR MODE switch to NORMAL. Speed will not droop with increased load. Also, with the VOLT REG MODE switch in the AUTO position, the voltage will not drop with an increase in the load.
8. Position the SYNC MONITOR switch to the OFF position. This causes the synchronizing monitor contacts to be disconnected from the CB. This, in turn, closes the circuit.
9. Depress the GTG START pushbutton momentarily to initiate the engine starting sequence. On LP air the generator should be up to speed in about 60 seconds. On HP air it should be up to speed in about 45 seconds. Automatic field flashing assures voltage buildup.
10. Return the GTG ALARM MONITOR switch to NORMAL. With the switchboard main bus energized, the white indicator lamp POWER SUPPLY 28 VOLTS DC AVAIL will illuminate. The red GTG alarming indicators, ON BATT and MALF, will be extinguished.
11. Check the voltmeter and frequency indicators for 450 volts and 60 Hz. Adjust as required. Adjust the voltage by using either the MAN MODE VOLT ADJ knob or the GEN VOLTAGE RAISE-LOWER switch.
12. Place the VOLT REG MODE switch to the AUTO position. This allows automatic regulation of the generator voltage to the reference set. This is done through the use of the GEN VOLTAGE RAISE-LOWER switch.
13. Turn the GEN VOLTAGE switch to adjust the voltage to 450 volts.
14. Return the GTG START AIR switch to LOW if HP air was used to start the GTG.

Paralleling a Generator to the Main Bus

Once the generator has been started and the main bus is energized by one of the on-line generators, use the following procedure to parallel the generator with the main bus.

1. Turn the VOLT/FREQ MTR switch to position 2. This selects the local GB. This action connects the voltmeter and frequency meter to monitor the switchboard bus. The generator has its own voltmeter and frequency meter connected at all times.
2. Turn the GEN VOLT switch to adjust the generator voltage to match the bus voltage.
3. Turn the CB SYNC CONT switch to position 2. This selects the local GB. This action activates the generator CB CONTROL switch for the closing operation.
4. Turn the SYNC MONITOR switch to SYNC. This action connects the synchronizing monitor relay contacts to the GB closing the circuit.
5. Check the synchroscope for synchronism. Adjust the generator frequency so the pointer rotates slowly clockwise (in the FAST direction).
6. Close the GB with its CB CONTROL switch as the synchroscope pointer approaches top center. Turning the CB CONTROL switch before pickup of the synchronizing monitor relay will prevent that relay from energizing.

7. Observe that the CLOSED indicator is illuminated and that the OPEN and GEN HTR ENRGZ indicators are extinguished.

8. Turn the CB SYNC CONT switch to OFF. This prevents the closing of the generator, shore power (in the case of switchboard No. 1), or either BTB from their individual control switches. It will also disconnect synchronizing voltages from the synchronizing monitor.

9. Ensure that the load is balanced. This step requires communication with other operators of on-line generator sets.

10. Place the CB MODE CONT switch to AUTO. When control is LOCAL, the AUTO position allows the GB to close automatically upon loss of switchboard voltage. This happens after the generator has come up to speed and desired voltage.

11. Turn the GTG CONTROL switch to REMOTE. This action transfers generator and switchboard control to the EPCC.

Paralleling Main Bus to Bus Tie

The main bus is energized by the local generator. The bus tie is energized by one of the two remaining generators. Before the generators are paralleled, the local BTB is in the OPEN position.

1. Ensure that the BTB indicator is in the CHARGED position. Also, ensure that the power switch on the breaker is in the ON position.

2. Ensure that the GTG CONTROL switch is in the LOCAL position. Paralleling is controlled at the switchboard.

3. Ensure that the CB MODE switch is in the PERM position. Putting the switch in PERM allows the BTB to be closed only through the synchronizing monitor.

4. Ensure that the SYNC MONITOR switch is in the SYNC position. This action connects the synchronizing monitor relay contacts to the BTB. It closes the circuit selected by the CB SYNC CONTROL switch.

5. Turn the VOLT/FREQ MTR switch to the bus tie designated for synchronization. This action connects the voltmeter and the frequency meter to the bus tie selected by the CB SYNC CONT switch.

6. Turn the GEN VOLT switch to adjust the generator voltage to match the bus tie voltage.

7. Turn the CB SYNC CONT switch to the bus tie designated for synchronization to activate the closing circuit of the selected BTB.

8. Check the synchroscope for synchronism. Adjust the generator frequency so the pointer rotates slowly clockwise (in the FAST direction).

9. Close the designated BTB with its CB CONTROL switch as the synchroscope pointer approaches top center (11 o'clock position). The blue lamp will illuminate indicating CB closure.

10. Turn the CB SYNC CONT switch to the OFF position. (Same action occurs as in step 8 under paralleling a generator to the main bus.)

11. Turn the VOLT/FREQ MTR switch to the MN BUS position. This connects the voltmeter and the frequency meter to the switchboard bus.

12. Ensure that the load is balanced. Load balancing requires communication with operators of other on-line GTGSs.

13. Turn the CB MODE switch to the AUTO position. When the control switch is in LOCAL, the CB MODE AUTO position provides for automatic closing of the GB upon loss of switchboard voltage after the generator has come up to speed and desired voltage.

14. Turn the GTG CONTROL switch to the REMOTE position. This action transfers control to the EPCC.

Removing Electrical Load

This procedure is used for any combination of generators in parallel when one of them is not required to supply the load.

1. Turn the GTG CONTROL switch to the LOCAL position. Generator control is now at the switchboard.

2. Turn the CB MODE CONT selector to the MNL position or to the PERM position. This prevents automatic reclosing of the GB upon loss of switchboard voltage.

3. Turn the GB switch to the TRIP position.

4. Observe that the CLOSED indicator is extinguished and that the OPEN and GEN HTR ENRGZ indicators are illuminated.

5. Stop the GT following the EOSS by momentarily depressing the STOP pushbutton.

SHORE POWER

The shore power CB is located at switchboard No. 1. This breaker, when closed, connects shore power to bus tie 1S-2S. The frequency selector switch on switchboard No. 1 has a shore power position. The breaker control switch is also located on the control panel. Ship's personnel CANNOT adjust either the voltage or frequency of shore power. Therefore, the switchboard control is designed so generator No. 1 can be paralleled with local shore power. This feature allows transfer of the ship's electrical load to and from shore power without a power interruption.

You can close the shore power CB in manual or manual permissive mode. When the synchronizing monitor is in the manual permissive position, the breaker will not close unless the frequency difference is less than 0.2 Hz, the voltage difference is less than 22 volts, and the phase relation is within 0 to +30 electrical degrees of synchronism.

Shifting Electrical Load From Shore Power to Ship's Power

With ship's electrical buses energized from shore power and GTGS No. 1 started as per EOSS, proceed as follows to shift the electrical load from shore to ship.

1. Turn the GOV/VR MODE switch to the DROOP position. Observe that the DROOP GOV and VR indicators are illuminated. Both the gas turbine speed and the generator voltage will decrease with increasing load.
2. Ensure that all BTBs are closed.
3. Turn the VOLT/FREQ MTR switch to the SHORE PWR position. This connects the voltmeter and the frequency meter to monitor the shore power bus.
4. Adjust the generator voltage to equal the shore voltage. Shore power may be as high as 480 volts.
5. Turn the CB SYNC CONT switch to the 1SG CB position. This actuates the generator CB CONTROL switch for the closing operation.
6. Turn the CB MODE CONT switch to the PERM position; turn the SYNC MONITOR switch to SYNC. These actions together activate the synchronizing monitor.
7. Turn the GEN FREQ switch until the synchroscope rotates slowly clockwise (in the FAST direction).
8. Close the GEN 1SG breaker as the synchroscope pointer approaches the top center position (11 o'clock position). Turning the CB CONTROL switch before pickup of the synchronizing monitor relay prevents that relay from energizing.
9. Turn the GEN FREQ switch to the RAISE position until the load has been shifted to the 1SG.
10. Trip the SHORE PWR CB.
11. Turn the CB SYNC CONT switch to the OFF position. This disables the generator breaker CB CONTROL switch.
12. Adjust the voltage to 450 volts and the frequency to 60 Hz.
13. Turn the GOV/VR CONT switch to the NORMAL position. Observe that the NORMAL GOV and VR indicators are illuminated. Positioning the switch to the NORMAL position takes the gas turbine speed and the generator voltage out of the DROOP mode.
14. Turn the CB MODE selector to the AUTO position. With the switchboard in LOCAL control, the AUTO CB MODE provides for automatic closure of the GB. This occurs if power is lost at the switchboard voltage after the generator has come up to speed and voltage.
15. Turn the GTG CONTROL switch to the REMOTE position to transfer control to the EPCC.
16. The white indicating lamp SHORE POWER AVAILABLE will remain illuminated until the shore power source is de-energized.

Shifting Electrical Load From Ship to Shore

Before the shift, shore power is connected in proper phase rotation to receptacles on the 03 level of the ship. The shore power breaker is open and generator No. 1 is supplying ship's power.

1. Ensure that all BTBs are closed and that the shore power breaker is open. Ensure that the SHORE POWER AVAILABLE indicator is illuminated.
2. Select the TEST position on the SHORE POWER PHASE SEQUENCE switch. Three

green lamps on the phase sequence indicator will illuminate if all three phases are connected and energized. If the white indicator lamp INCORRECT PHASE SEQUENCE CBA illuminates, shore power must be de-energized and two phase leads must be reversed. With correct shore power connections, the white indicator CORRECT PHASE SEQUENCE ABC will illuminate. Turn the phase sequence switch to the OFF position.

3. Turn the GTG CONTROL switch to the LOCAL position. This action places control at the switchboard.

4. Turn the GB MODE CONT switch to the PERM position. Turn the SYNC MONITOR switch to the SYNC position. This activates the synchronizing monitor.

5. Turn the VOLT/FREQ MTR switch to position 5 which selects the shore power breaker. This connects the voltmeter and the frequency meter to monitor shore power.

6. Turn the GOV/VR CONT switch to the DROOP position. Observe that the DROOP GOV and VR indicators are illuminated. Both gas turbine speed and generator voltage will decrease as the load increases.

7. Adjust the generator voltage to equal shore voltage. When the generator voltage is raised beyond 472 volts, HIGH VOLTAGE audible and visual alarms will occur at the EPCC.

8. Turn the CB SYNC CONT switch to the SHORE PWR CB position. This activates the shore power CB CONTROL switch for the closing operation.

9. Adjust the generator frequency until the synchroscope pointer rotates slowly counterclockwise (in the SLOW direction).

10. Close the SHORE PWR CB before the synchroscope pointer reaches the top center position. Turning the CB CONTROL switch before pickup of the synchronizing monitor relay will prevent that relay from energizing.

11. Turn the GEN FREQ switch to the LOWER position. Turn until the generator wattmeter pointer indicates the first numerical increment above zero on the meter scale.

12. Trip the GEN 1SG breaker. Observe that the CLOSED indicator is extinguished and that the OPEN and GEN HTR ENRGZ indicators are illuminated.

13. Turn the CB SYNC CONT switch to the OFF position. This disables the shore power CB CONTROL switch closing function.

14. Turn the GOV/VR MODE switch to the NORMAL position. Observe that the NORMAL GOV and VR indicators are illuminated. Positioning the switch to the NORMAL position takes the gas turbine speed and the generator voltage out of the DROOP mode.

15. Stop the GT following the EOSS by momentarily depressing the STOP pushbutton.

PLACING IN STANDBY

The GTGS must have been shut down. Then proceed as follows.

1. Ensure GB and BTB power switches are in the ON position.
2. Ensure VOLT REG MODE switch is in AUTO. This provides for automatic regulation of generator voltage.
3. Ensure GTRB GEN CLG FAN (NORM) and GTGB SW PUMP circuit breakers are closed. This allows fan and pump to run when voltage is on the generator.
4. Ensure GEN HTR ENRGZ switch is in the ON position. This enables the heaters to energize when the GB is open.
5. Ensure CB MODE switch is in AUTO. When in LOCAL control, this will enable the GB to be automatically closed on loss of switchboard voltage and after the generator has reached speed and voltage.
6. Ensure GTG ON STANDBY is illuminated.
7. Turn GTG CONTROL switch to REMOTE. Control is transferred to EPCE. The GTGS is now ready to start and come on the line under automatic control.

AUTOMATIC OPERATION AND PROTECTIVE DEVICES

Many devices are used in the switchboard to provide automatic operation or protect the generator. These devices include reverse power, over power, under frequency, and fault current protection. Also included are dead bus start and auto load shedding circuits. The devices and circuits require no operator action to enable

them. But, you must be aware of their function so you can identify the actions if they operate.

Reverse Power

Sometimes a generator's prime mover stops producing power but the generator is still connected to the bus through the GB. In this case, the generator will start acting as a load. This could cause the generator to rotate in reverse and possibly damage the prime mover. To prevent this condition known as reverse power from damaging equipment, a reverse power relay is used. This relay is a solid-state electronic circuit. It measures the amount of reverse power and sends a signal to trip the GB at a preset parameter. The set point used is normally between 10 to 15 percent reverse power.

Overpower Relay

The overpower relay is used to sense overpower conditions on the generator output. It is also a solid-state device. The overpower relay activates load shed circuits if the ship's load is higher than the output of the generator on line. When load conditions reach a preset value, the relay sends out a signal to activate the load shed circuits. Normally, the preset value is about 110 percent for 2 seconds.

Under Frequency Relay and Dead Bus Start

The under frequency relay, used on DD-963, DDG-993, and CG-47 classes, is used for dead bus logic in the switchboard. It is also used to activate the waste heat boiler. It can send out generator run signals to the EPCC and send a permissive to close the GB. This relay activates at 57 Hz to output the required signals. With the generator not running and the switchboard in local control (with the CB mode control switch in AUTO), a loss of bus voltage will start the GTG. It will start on HP air provided the LOCOP is in remote control. When generator frequency rises to 57 Hz, the under frequency relay outputs a signal to open both switchboard bus ties. When these open, the switchboard logic will issue a close command to the GB. This will restore power to that individual switchboard and isolate it from the other two switchboards. If the switchboard is in remote, these actions will not occur, but the GTG will start and come up to run.

Fault Current System

The fault current system was installed on all DD-963, DDG-993, and CG-47 class ships after it was discovered that bus ties could be automatically closed to a shorted switchboard. Fault current will inhibit some of the auto recovery capabilities of the EPCC. It does this if a major short circuit in the 60-Hz bus occurs. Each switchboard has an independent fault current detector (FCD) system. It is tied to a common alarm panel in CCS. If a direct short occurs in the bus work or cabling of the 60-Hz system, total current will increase drastically. The current excess will also drag generator frequency down. When the FCD detects current of 5000 amperes and frequency of 59 Hz, it will take action. Each FCD operates independently of the other. When the fault is detected, the FCD issues commands to open the two BTBs on the switchboard. It inhibits their closure. This isolates the switchboard. It prevents auto recovery from closing bus ties to a faulted switchboard. The FCD will also send signals to the alarm panel to alert the EPCC operator of the action it has taken. After correction of the fault condition, you must reset the FCD before closure of the inhibited bus ties.

Load Shed

If the ship's load is higher than the capacity of the on-line generators, some load must be shed. If high load conditions are allowed to exist for too long, they may cause the GB to open. The switchboards on gas turbine ships have been equipped with load shed circuitry to reduce high loads quickly. When an overpower condition exists on a switchboard for longer than normal, transient time load shed is automatically activated. This overpower is detected by the overpower relay. When power is at 110 percent for more than 2 seconds, the relay will activate the load shed circuits. Only one overpower relay must activate to initiate load shed on all switchboards. The load shed circuits activate the shunt trips of preselected

CBs. They trip them and reduce the load. Normally, only the least vital loads are shed first. On ships with more than one stage of load shed, the overpower condition must continue for several more seconds. Then it can activate the next stage. You can manually activate load shed from the switchboards on FFG-7 class ships. You can manually activate load sheds at the EPCC on DD-963, DDG-993, and CG-47 class ships.

SUMMARY

This chapter and the associated NRCC should have helped you understand the operation and construction of the 60-Hz equipment you may encounter as a GSE. However, there is no substitute for technical manuals when actually performing maintenance on any of this equipment. The EOSS is also provided to give you a step-by-step procedure when operating any of this vital equipment. Remember, when working around electrical equipment, safety is the most important aspect of the job. Use the tag-out procedures, test your meters, use the two-man rule, and do not bypass any safety devices.

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APPENDIX I

GLOSSARY

ACTION CUTOUT (ACO) SWITCH.—A switch that provides interconnection primarily for maintenance purposes to isolate a console completely from the serial data loops or to isolate a certain interconsole segment of the data loop from the system.

AFTER STEERING CONTROL UNIT.—A rudder command generator that electrically controls rudder angle.

AMPERE (amp).—A unit of electrical current or rate of flow of electrons. One volt across one ohm of resistance causes a current flow of one ampere.

ANALOG SIGNAL.—A measurable quantity that is continuously variable throughout a given range and is representative of a physical quantity.

ANALOG TO DIGITAL (A/D) CONVERSION.—A conversion that takes an analog input in the form of electrical voltage or current and produces a digital output.

ANNULAR.—In the form of, or forming a ring.

ANTI-ICING.—A system for preventing buildup of ice on the gas turbine intake systems.

AQUEOUS FILM FORMING FORM (AFFF).—A light chemical that, when mixed with seawater, produces a fire-extinguishing foam that covers a liquid fire and separates the fire from its oxygen supply.

AUTOMATIC BUS TRANSFER (ABT).—Normal and alternate power sources are provided to vital loads. These power sources are supplied from separate switchboards through separated cable runs. Upon loss of the normal power supply, the ABT automatically disconnects this source and switches the load to the alternate source.

AUTOMATIC PARALLELING DEVICE (APD).—Automatically parallels any two generators when initiated by the EPCC.

AUXILIARY CONTROL CONSOLE (ACC).—The console in CCS used to monitor the FFG-7 class auxiliary systems.

BABBITT.—A white alloy of tin, lead, copper, and antimony that is used for lining bearings.

BLEED AIR.—Hot compressed air bled off the compressor stages of the GTMs and GTGS. See BLEED AIR SYSTEM.

BLEED AIR SYSTEM.—This system uses as its source compressed air extracted from the compressor stage of each GTM or GTGS. It is used for anti-icing, prairie air, masker air, and LP gas turbine starting for both the GTMs and GTGS.

BLOW-IN DOOR.—Doors located on the high hat assembly designed to open by solenoid-operated latch mechanisms if the inlet air flow becomes too restricted for normal engine operation.

BORESCOPE.—A small periscope (instrument) used to visually inspect internal engine components.

BOUNDARY LAYER INFRARED SUPPRESSION SYSTEM (BLISS).—The infrared suppression system used on CG-47 class ships that use large eductors to mix cool air with GT exhaust.

BRIDGE WING DISPLAY UNIT.—Part of ship control equipment (SCE). One bridge wing display unit is mounted on the port and one on the starboard bridge wing. Each bridge wing display unit displays actual port and starboard shaft rpm and standard orders.

BUFFER.—Used to electronically isolate and filter an electrical signal from its source.

BUILT-IN TEST EQUIPMENT.—Electronic circuitry in ECSS and CRP propeller control equipment; used to test for proper circuit operation.

BUS.—An uninsulated power conductor (a bar of wire).

BUS TIE BREAKER (BTB).—Used to connect one main switchboard to another main switchboard.

CENTRAL CONTROL STATION (CCS).—The main operating station from which a majority of the engineering plant machinery can be controlled and monitored.

CENTRAL INFORMATION SYSTEM EQUIPMENT (CISE).—Located in CCS and is part of the PAMISE. It includes the general purpose digital computer (ECU), S/CE No. 1, and supporting equipment.

CHEMICAL, BIOLOGICAL, RADIATION (CBR) WASHDOWN.—The saltwater washdown system for decontamination of the ship's external surfaces.

CIRCUIT BREAKER (CB).—An automatic protective device that, under abnormal conditions, will open a current-carrying circuit.

CLUTCH/BRAKE ASSEMBLY.—A clutch/brake assembly for each GTM engine is mounted on the MRG housing to couple or decouple either or both engines to the drive train, to stop and hold the power turbine, and for shaft braking.

COALESCE.—To grow together, unite, or fuse, as uniting small liquid particles into large droplets. This principle is used to remove water from fuel in the filter/separator.

COMPRESSOR DISCHARGE PRESSURE (CDP).—Compressor discharge pressure is sensed by a pressure tap on the compressor discharge static pressure sensing line to the MFC and piped to a base-mounted transducer on the GTM.

COMPRESSOR INLET TEMPERATURE (CIT OR T_2).—The temperature of the air entering the gas turbine compressor (GTM) as measured at the front frame; one of the parameters used for calculating engine power output (torque) and scheduling combustion fuel flow and variable stator vane angle.

COMPRESSOR INLET TOTAL PRESSURE (P_{t2}).—Sensed by a total pressure probe mounted in the GTM compressor front frame.

CONTROL AIR SYSTEM.—The equipment that controls the compressed air used to operate the main clutch/brake assemblies. One control air system unit is mounted on each side of each MRG.

CONTROLLABLE REVERSIBLE PITCH (CRP) PROPELLER.—A propeller whose blade pitch can be varied to control amount of thrust in both ahead and astern directions. (Known as controllable pitch propeller on FFG-7 class.)

DAMAGE CONTROL CONSOLE (DCC).—Located in CCS and provides monitoring for hazardous (fire, high bilge levels, and so forth) conditions. It also monitors the ship's firemain and can control the fire pumps.

DEAERATOR.—A device that removes air from oil as in the lube oil storage and conditioning assembly tank (GTM) that separates air from the scavenge oil.

DEMAND DISPLAY INDEX (DDI).—A numerical display at the consoles that is used to read values of parameters within the engineering plant.

DEMISTERS.—A moisture removal device (GTM intake system) that separates water from air.

DIFFUSER.—A device that reduces the velocity and increases the static pressure of a fluid passing through a system.

DIGITAL SIGNAL.—A signal in the form of a series of discrete quantities that have two distinct levels (for example, on/off).

DIGITAL TO ANALOG (D/A) CONVERSION.—A conversion that produces an analog output in the form of voltage or current from a digital input.

DISTILLATE.—The fresh water that is obtained from the distilling process.

EDUCTOR.—A mixing tube (jet pump) that is used in the GTM exhaust system. It is physically positioned at the top of the stack so the gas flow from the GTM exhaust nozzles will draw outside air into the exhaust steam as it enters the mixing tube. It may also be a liquid pump used to dewater bilges and tanks.

ELECTRIC PLANT CONTROL CONSOLE (EPCC).—Contains the controls and indicators used to remotely operate and monitor the generators and the electrical distribution system.

ELECTRIC PLANT CONTROL ELECTRONIC ENCLOSURE (EPCEE).—A part of the EPCE and contains power supplies that provide the various operating voltage required by the EPCC.

ELECTRIC PLANT CONTROL EQUIPMENT (EPCE).—Provides centralized remote control of the GTGS and electrical distribution equipment. The EPCE includes the EPCC and EPCEE and is located in CCS.

ELECTRONIC GOVERNOR (EG).—A system that uses an electronic control unit with an electrohydraulic governor actuator to control the position of the LFV on the GTGS and regulate engine speed.

ENGINE ORDER TELEGRAPH (EOT).—A nonvoice communication system provided between the command station (pilothouse), CCS, and MER.

ENGINEERING CONTROL AND SURVEILLANCE SYSTEM (ECSS).—An automatic electronic control and monitoring system using analog and digital circuitry to control the propulsion and electric plant. The ECSS consists of the PLOE, PAMCE, SHIP CONTROL EQUIPMENT, EPCE, and PAMISE.

ENGINEERING OPERATIONAL SEQUENCING SYSTEM (EOSS).—A system of operating instructions bound in books for each watch station. It provides detailed operating procedures for the propulsion plant.

EXECUTIVE CONTROL UNIT (ECU).—A computer (part of PAMISE) that is the nucleus of the information center of the ECSS. The ECU gathers data information from the ship's propulsion, auxiliary, and electric plant equipment.

FAULT ALARM.—This type of alarm is used in the FO control system and the DCC. It indicates that a sensor circuit has opened.

FIREMAIN SYSTEM.—A seawater system provided for the primary purpose of extinguishing shipboard fires and controlling CBR decontamination. The firemain has a secondary function to supply seawater to other systems such as equipment cooling and waste disposal.

FOREIGN OBJECT DAMAGE (FOD).—Damage as a result of entry of foreign objects into a gas turbine inlet.

FREE STANDING ELECTRONIC ENCLOSURE (FSEE).—Provides the supporting electronics and engine control interface between the GTM and the control consoles. One FSEE is located in each MER.

FUEL OIL (FO) SYSTEM.—Provides a continuous supply of clean fuel to the GTMs.

FUEL OIL TRANSFER, BALLAST CONTROL PANEL.—Located in CCS and is used to monitor the ship's fuel tanks.

FUEL SYSTEM CONTROL CONSOLE (FSCC).—Located in CCS and is the central station for monitoring and control of the fuel fill and transfer system.

FULL POWER CONFIGURATION.—The condition in which both engines (GTM) of a set are engaged and driving the reduction gear/propeller shaft.

GAS GENERATOR (GG).—The HP section of the main propulsion GT. It includes the compressor, combustor, HP turbine, front frame, compressor rear frame, turbine mid frame, transfer gearbox, and the controls and accessories.

GAS GENERATOR SPEED (N_{GG}).—Sensed by a magnetic pickup on the aft transfer gearbox of the GTM.

GAS TURBINE (GT).—Gas turbine engines provide main propulsion power and drive the SS generator sets.

GAS TURBINE GENERATOR SET (GTGS).—Has a GTE, a reduction gearbox, and a three-phase alternating current generator rated at 2000 or 2500 kW and 450 volts a.c.

GAS TURBINE MODULE (GTM).—Consists of the main propulsion gas turbine unit including the GTE, base, enclosure, shock mounting system, fire detection and extinguishing system, and the enclosure environmental control components.

GENERATOR BREAKER (GB).—Used to connect a generator to its main switchboard.

GENERATOR CONTROL UNIT (GCU).—A static GCU is supplied for each GTGS consisting of a static exciter/voltage regulator assembly, field rectifier assembly, motor-driven rheostat, and a mode select rotary switch. It controls the output voltage of the generator.

GOVERNOR DROOP MODE.—Droop mode is normally used only for paralleling with shore power. Since shore power is an infinite bus (fixed frequency), droop mode is necessary to control the load carried by the generator. If a generator paralleled with shore power and one attempts to operate in isochronous mode instead of droop mode, the generator governor speed reference can never be satisfied because the generator frequency is being held constant by the infinite bus. If the generator governor speed reference is above the shore power frequency, the load carried by the generator will increase beyond capacity (overload) in an effort to raise the shore power frequency. If the speed reference is below the shore power frequency, the load will decrease and reverse (reverse power) in an effort to lower the shore power frequency. The resulting overload or reverse power will trip the GB.

GOVERNOR ISOCHRONOUS MODE.—Normally used for generator operation. This mode provides a constant frequency for all load conditions. When operating two (or more) generators in parallel, isochronous mode also provides equal load sharing between units.

HAZARD ALARM.—This type of alarm is used in the FO control system and DCC. It shows that a parameter has exceeded preset safe limits.

HEAD TANK.—Located higher than other system components to provide a positive pressure to a system by gravity (for example, gravity feed tanks [FO service system] and CRP propeller system head tank).

HEADER.—A piping manifold that connects several sublines to a major pipeline.

HELIX.—A tube or solid material (gear teeth) wrapped like threads on a screw.

HERTZ (Hz).—A unit of frequency equal to one cycle per second.

HIGH HAT ASSEMBLY.—A removable housing over the main engine air intake ducts that contains the moisture separation system (demisters), inlet louvers, and blow-in doors.

HIGH-PRESSURE (HP) AIR (3000 psig) SYSTEM.—Used for emergency starting of the GTMs and GTGS. It is also used in operating the ASROC launcher, 5-inch guns, torpedo tubes, helicopter services, and as a backup emergency supply for the SSAS.

HUMIDITY, ABSOLUTE.—The weight of water vapor in grains per cubic foot of air.

HUMIDITY, RELATIVE.—The ratio of the weight of water vapor in a sample of air to the weight of water vapor that same sample of air contains when saturated.

HUMIDITY, SPECIFIC.—The weight of water vapor in grains per pound of dry air.

HYDRAULIC OIL POWER MODULE (HOPM).—Located near the MRG it delivers control oil and HP oil to an oil distribution box (located at the end of each propeller shaft) for distribution to the propeller hub and actuation of the pitch control rod within the shaft.

IMPINGE.—To strike, hit, or be thrown against, as in the case of condensate impinging against the tubes and baffles.

INFORMATION CONTROL CONSOLE (ICC).—Part of the ECU. ICC No. 1 is the panel used to program and run the computer. ICC No. 2 is the tape reader used to input the program into the ECU.

INFRARED (IR) SUPPRESSION.—Used to reduce GTGS exhaust temperature by injecting a seawater spray into the exhaust gases. This is designed to reduce the possibility of detection by heat-seeking devices.

INLET GUIDE VANES (IGVs).—Vanes ahead of the first stage of compressor blades of a GTE. Their function is to guide the inlet air into the GT compressor at the optimum angle.

INLET PLENUM.—That section of the GTE inlet air passage that is contained within the engine enclosure. Applies to GTM and GTGS engines.

INTEGRATED THROTTLE CONTROL (ITC).—Has control electronics located in the PACC, that allows single lever control of throttle and pitch of one shaft. Two levers (one per shaft) are located at the SCC and at the PACC.

JET ENGINE FUEL (JP-5).—The principal use of JP-5 is fuel for the helicopter and small boats. The JP-5 system has the designed capability to provide fuel to GTMs and generators in emergencies.

LABYRINTH/HONEYCOMB SEALS.—Combine a rotating element and a honeycomb stationary element to form an air seal. Used in the GTM turbine to maintain close tolerances over a large temperature range.

LABYRINTH/WINDBACK SEALS.—Combine a rotating element with a smooth surface stationary element to form an oil seal. This type of seal is used with an air seal with a pressurization air cavity between the two seals. Pressure in the pressurization air cavity is always greater than the sump pressure. Therefore, flow across the seal is toward the sump. This prevents oil leakage from the sump. The windback is a coarse thread on the rotating element of the oil seal which uses screw action (windback) to force any oil that might leak across the seal back into the sump.

LIGHT EMITTING DIODE (LED).—A solid-state device that, when conducting, emits light. The LEDs are used for the digital displays and card fault indicators in electronic systems.

LIQUID FUEL VALVE (LFV).—Meters the required amount of fuel for all engine operating conditions for the GTGS engine.

LOAD SHEDDING.—Generator overpower protection by automatically dropping preselected nonvital loads when generator output reaches 100 percent for 3 seconds, and additional dropping of preselected semivital loads if the overload condition exists for another 5 seconds.

LOCAL CONTROL.—Start-up and operation of equipment by manual controls attached to the machinery, or by electric panel attached to the machinery or located nearby.

LOCAL OPERATING PANEL (LOP).—The local operating station for GTMs on the FFG-7 class. It is located in the MER.

LOCAL OPERATING STATION (LOS).—One LOS is in each MER. Each LOS consists of a PLCC and PLCEE (components of PLOE) on Spruance-type ships and an LOP on Perry class ships.

LOCKED TRAIN.—A designation applied to a double reduction gear set having dual or twin torque paths.

LOOPSEAL.—A vertical *U* bend designed to permit liquid flow between stages of a system, but prevent equalizing of stage pressure.

LUBE OIL STORAGE AND CONDITIONING ASSEMBLY (LOSCA).—Mounted remotely from the GTM and is a unit with a lube oil storage tank, heat exchanger, scavenge oil duplex filter, and scavenge oil check valve (all mounted on a common base). Its function is to provide the GTM with an adequate supply of cooled, clean lube oil. It also has instrumentation for remote monitoring of oil temperature, filter differential pressure, and high/low tank level alarm.

MAIN FUEL CONTROL (MFC).—A hydromechanical device on the propulsion gas turbine that controls N_{GG}, schedules acceleration fuel flow, deceleration fuel flow, and stator vane angle for stall-free, optimum performance over the operating range of the GT.

MAIN REDUCTION GEAR (MRG) ASSEMBLY.—A locked train, double reduction gear used on gas turbine ships. It allows the PT and the CRP propeller to operate at the most efficient speed.

MANUAL BUS TRANSFER (MBT) SWITCH.—Provides selection between normal and alternate power sources for selected equipment. This transfer switch is used for controllers with low voltage protection that requires manual restarting after voltage failure and for electronic power distribution panels.

MASKER AIR SYSTEM.—Disguises the signature of the ship's hull and alters transmission of machinery noise to the water by emitting air from small holes in the emitter rings on the ship's hull. This reduces the reliability of ship identification by sonar.

MICRON.—A unit of length equal to one millionth of a meter.

MIL.—A unit of length equal to one thousandth of an inch.

MOST REMOTE BEARING.—The designated most remote MRG bearing is the lower outboard, turbine end, first reduction gear bearing.

MULTIPLEXING.—A system of transmitting two or more messages or signals over a common circuit.

NAVY DISTILLATE.—A Navy classification of a distillate FO.

NOZZLE.—A small jet (hole) at the end of a pipe.

OIL DISTRIBUTION BOX.—Located at the forward end of each MRG assembly. It directs HP hydraulic oil from the HOPM to the propeller hub through the shaft bore. The oil distribution box also establishes propeller pitch by using control oil from the HOPM to position the valve rod, which extends through the shaft to the hub.

ORIFICE.—A restricted opening used primarily in fluid systems.

PERMANENT MAGNET ALTERNATOR (PMA).—Mounted on the generator shaft extension of each GTGS and supplies speed sensing and power to the EG. The PMA also supplies initial generator excitation.

PINION.—A smaller gear designed to mesh with a larger gear.

PITCH.—A term applied to the distance a propeller will advance during one revolution.

POPPET-TYPE CHECK VALVE.—A valve that moves into and from its seat to prevent oil from draining into the GTGS when the engine is shut down.

PORTABLE STEERING CONTROL UNIT.—Part of the ship control equipment (SCE) and provides control of ship's steering from bridgewing locations.

POUNDS PER SQUARE INCH (psi).—Unit of pressure.

POUNDS PER SQUARE INCH ABSOLUTE (psia).—Unit of pressure.

POUNDS PER SQUARE INCH DIFFERENTIAL (psid).—Unit of pressure. Also known as delta (Δ) pressure.

POUNDS PER SQUARE INCH GAUGE (psig).—Unit of pressure.

POWER LEVER ANGLE (PLA).—A rotary actuator mounted on the side of the GTM fuel pump and its output shaft lever. It is mechanically connected to the MFC power lever. The PLA actuator supplies the torque to position the MFC power lever at the commanded rate.

POWER ON RESET.—A signal generated by each electronics enclosure when it is energized. This signal preconditions electronic circuitry in the control console (whose power is supplied by that electronics enclosure) to a known state for operational purpose during application of power to the console.

POWER TAKEOFF (PTO).—The drive shaft between the GTGS gas turbine engine and the reduction gear. Transfers power from the gas turbine to the reduction gear to drive the generator.

POWER TURBINE (PT).—The GTM turbine that converts the GG exhaust into energy and transmits the resulting rotational force via the attached output shaft.

POWER TURBINE INLET TEMPERATURE ($T_{5.4}$) .—Temperature sensed by thermocouples installed in the GTM mid frame.

POWER TURBINE INLET TOTAL PRESSURE ($P_{t5.4}$).—Pressure sensed by five total pressure probes located in the GTM turbine mid frame and piped to a transducer on the bottom of the GTM.

POWER TURBINE SPEED (N_{pt}).—GTM power turbine speed is sensed by magnetic pickups in the GTM turbine rear frame.

PRAIRIE AIR SYSTEM.—Disguises the sonar signature of the ship's propellers by emitting cooled bleed air from small holes along the leading edges of the propeller blades. The resulting air bubbles disturb the thrashing sound so identification of the type of ship through sonar detection becomes unreliable.

PRINTED CIRCUIT BOARD (PCB).—An electronic assembly mounted on a card, using etched conductors. Also called printed wire board.

PROPULSION AND AUXILIARY CONTROL CONSOLE (PACC).—Located in CCS and part of the PAMCE. It contains the electronic equipment capable of controlling and monitoring both propulsion plants and auxiliary equipment.

PROPULSION AND AUXILIARY CONTROL ELECTRONIC ENCLOSURE (PACEE).—Located in CCS and has the electronics that supply power to the PACC.

PROPULSION AND AUXILIARY MACHINERY CONTROL EQUIPMENT (PAMCE).—Located in CCS and is part of the ECSS and includes the PACC and PACEE. This equipment provides centralized control and monitoring of both main propulsion plants and auxiliary machinery.

PROPULSION AUXILIARY MACHINERY INFORMATION SYSTEM EQUIPMENT (PAMISE).—Located in CCS and is part of the ECSS. This equipment receives, evaluates, and logs the engineering plant performance, status, and alarm state. The PAMISE contains the CISE and S/CE No. 1.

PROPULSION CONTROL CONSOLE (PCC).—The main engine control console in CCS on FFG-7 class ships. It is used for starting, stopping, and controlling the GTMs and propeller shaft.

PROPULSION LOCAL CONTROL CONSOLE (PLCC).—Located in each engine room and is part of the PLOE. It has controls and indicators necessary for operator's control of one main propulsion plant and its supporting auxiliaries.

PROPULSION LOCAL CONSOLE ELECTRONIC ENCLOSURE (PLCEE).—Located in each engine room and is part of the PLOE. It has the electronics that supply power to the FSEE and PLCC.

PROPULSION LOCAL OPERATING EQUIPMENT (PLOE).—Located in each engine room and is part of the ECSS. It includes the PLCC and PLCEE. The PLOE provides for local control and monitoring of the main propulsion GTE and the associated auxiliary equipment.

PUSHBUTTON SWITCH INDICATOR.—A panel-mounted device that has both switch contacts and indicating lights. The contacts are actuated by depressing the device face. The indicator lights are labeled and wired for indicating alarm or status information.

RADIO-FREQUENCY INTERFERENCE.—An electrical signal capable of being propagated into and interfering with the proper operation of electrical or electronic equipment.

REDUCTION STATION.—A reduction valve that reduces fluid pressure to a usable level for a particular service.

RESISTANCE TEMPERATURE DETECTOR (RTD).—Same as RTE.

RESISTANCE TEMPERATURE ELEMENT (RTE).—These temperature sensors work on the principle that as temperature increases, the conductive material exposed to this temperature increases its electrical resistance.

RISER.—A distribution pipe extending vertically.

RPM AND PITCH INDICATOR UNIT.—Mounted in the pilothouse and is part of ship control equipment. It is identical to the BWDU except that it also displays port and starboard CRP propeller pitch.

RUDDER COMMAND SERVO UNIT.—An electrical/mechanical device that translates electrical rudder commands (received from the SCC or the ASCU) and converts them to a rotary motion. It has a drive assembly and a control assembly mounted on the differential control assembly.

SALIENT POLE GENERATOR.—A generator whose field poles are bolted to the rotor, as opposed to a generator whose field poles are formed by imbedding field windings in slot in a solid rotor.

SALINITY INDICATOR.—An indicator used for measuring the amount of salt in a solution.

SCAVENGE PUMP.—Used to remove oil from a sump and return it to the oil supply tank.

SECURED PLANT CONFIGURATION (MODE).—The condition in which engines of a set (GTM) are disengaged from the reduction gear/propulsion shaft.

SENSOR.—A device that responds to a physical stimulus and transmits a result impulse for remote motoring.

SERIAL DATA BUS.—Major communication link between ship control equipment, PAMCE, and PLOE. The bus is time-shared between the consoles. Control and status information is exchanged in the form of serial data words.

SERVICE TANKS.—The service tanks obtain fuel from the storage tanks to supply fuel to the service systems.

SHIP CONTROL CONSOLE (SCC).—Located on the bridge and is part of the SCE. It has equipment for operator control of ship's speed and direction.

SHIP CONTROL EQUIPMENT.—Bridge-located equipment of the ECSS and includes SCC, SCEEE, PSCU, BWDU, and RPIU.

SHIP CONTROL EQUIPMENT ELECTRONIC ENCLOSURE (SCEEE).—The SCEEE (located in CIC) is part of ship control equipment. It has power supplies that provide the various operating voltages required for the SCC, BWDU, and RPIU.

SHIP'S SERVICE AIR SYSTEM (SSAS).—Supplies LP compressed air at 150 psig and 100 psig to a majority of the ship's pneumatically operated equipment.

SIGNAL CONDITIONING ENCLOSURE (S/CE).—Part of the PAMISE and provides the major input interface between the propulsion plant machinery and the ECSS control consoles. The S/CE accepts inputs from the plant machinery and outputs normalized signals to the ECSS control consoles. Also has alarm detection and alarm output circuitry. One S/CE is located in each main engine room and one is part of the CISE (located in CCS).

SPLIT PLANT CONFIGURATION (MODE).—The condition in which only one engine of a set (GTM, A or B) is engaged and driving the reduction gear/propulsion shaft.

STALL.—An inherent characteristic of all gas turbine compressors to varying degrees and under certain operating conditions. It occurs whenever the relationship between air pressure, velocity, and compressor rotational speed is altered to such an extent that the effective angle of attack of the compressor blades becomes excessive, causing the blades to stall in much the same manner as an aircraft wing.

STANCHIONS.—Columns or supports for decks, handrails, and so forth. Stanchions are made of pipe, steel shapes, or rods according to the location and purpose they serve.

START AIR COMPRESSOR (SAC).—An LP air compressor, driven by the SSDGs, that provides air to start the GTMs on FFG-7 class ships.

SUMMARY ALARM/FAULT.—An indicator at a console that indicates to an operator that one of several abnormal conditions has occurred on a certain piece of equipment.

SWITCHBOARD (SWBD).—A large panel assembly that mounts the control switches, CBs, instruments, and fuses essential to the operation and protection of electrical distribution systems.

SWITCH INDICATOR.—Same as PUSH-BUTTON SWITCH INDICATOR.

TANK STRIPPING.—Stripping is the process of removing normally small amounts of water that collect in the bottom of fuel or other tanks.

TRANSDUCER.—A sensor that converts quantities such as pressure, temperature, and flow rate into electrical signals.

TURBINE INLET TEMPERATURE (TIT).—The GTGs turbine inlet temperature.

TURBINE OVERTEMPERATURE PROTECTION SYSTEM (TOPS).—A system found on DDG and CG class ships used to protect a surviving generator from overload in the event of another generator failure.

TURNING GEAR.—Drives the upper inboard second reduction pinion of the MRG through a manually operated connect-discount type of coupling to slowly rotate the gear elements and propeller shaft.

ULTRAVIOLET (UV) FLAME DETECTORS.—Sense the presence of fire in the GTM and GTGS and generate an electrical signal that is set to the ECSS.

UNINTERRUPTIBLE POWER SUPPLY (UPS) SYSTEM.—Critical ship control systems have a UPS as an emergency power source to maintain operations during any interruption of the normal electric power system.

VARIABLE STATOR VANE (VSV).—Compressor stator vanes that are mechanically varied to provide optimum, stall-free compressor performance over a wide operating range. The inlet guide vanes (IGVs) and stage 1 through 6 stator vanes of the main propulsion gas turbine compressors are variable.

WASTE HEAT BOILER.—Each waste heat boiler is associated with a GTGS and uses the hot GT exhaust to convert feedwater to steam for various ship's services.

APPENDIX II

ABBREVIATIONS AND ACRONYMS

This appendix is a listing of the abbreviations and acronyms used in this text. Although this is an extensive listing, it is not an all inclusive list of abbreviations and acronyms used by Gas Turbine System Technicians. However, this list will form a basis for your qualification under the PQS system and allow for rapid access to terms used by Gas Turbine System Technicians.

The first column lists the abbreviation/acronym and its full name. The second column lists the chapter in this text where the abbreviation/acronym was first introduced.

ABBREVIATION/ACRONYM		CHAPTER
	A	
ABT	— automatic bus transfer	11
a.c.	— alternating current	3
ACC	— auxiliary control console	10
ACO	— action cutout	9
A/D	— analog to digital	7
ADC	— analog to digital converter	8
AFFF	— aqueous film forming foam	9
Amp-hr	— ampere-hours	11
APD	— automatic paralleling device	8
	B	
BLISS	— boundary layer infrared suppression system	5
BTB	— bus tie breaker	9

ABBREVIATION/ACRONYM—CONTINUED		CHAPTER
C		
CB	— circuit breaker	9
CBR	— chemical, biological, radiation	9
CCS	— central control station	1
CDP	— compressor discharge pressure	5
CHT	— collecting, holding, and transfer	10
CISE	— central information system equipment	9
CIT	— compressor inlet temperature	4
CMD	— command	7
CO_2	— carbon dioxide	5
CODAG	— combined diesel and gas	4
CODOG	— combined diesel or gas	4
COGOG	— combined gas or gas	4
COSAG	— combined steam and gas	4
CPP	— controllable pitch propeller	3
CRP	— controllable reversible pitch	6
CSMP	— current ships maintenance project	1
CT	— current transformer	8
D		
DAC	— digital to analog converter	8
DB	— distribution box	12
d.c.	— direct current	3
DCC	— damage control console	8
DDI	— demand display indicator	6
DP	— distribution panel	12
DVM	— digital voltmeter	2

ABBREVIATION/ACRONYM—CONTINUED		CHAPTER
E		
ECM	— electronic control module	6
ECSS	— engineering control and surveillance system	8
ECU	— executive control unit	9
EDO	— engineering duty officer	1
EG	— electric governor	8
EM	— Electrician's Mate	1
EMI	— electromagnetic interference	5
EN	— Engineman	1
EOCC	— engineering operational casualty control	1
EOOW	— engineering officer of the watch	1
EOP	— engineering operational procedures	1
EOSS	— engineering operational sequencing system	1
EOT	— engine order telegraph	6
EPCC	— electric plant control console	8
EPCE	— electric plant control equipment	8
EPCEE	— electric plant control electronic enclosure	11
ESO	— educational services officer	1
F		
FCD	— fault current detector	12
FMP	— fuel manifold pressure	6
FO	— fuel oil	3
FOD	— foreign object damage	3
FSCC	— fuel system control console	9
FSEE	— free standing electronics enclosure	2

ABBREVIATION/ACRONYM—CONTINUED		CHAPTER
ft-lb	— foot pound	2
ft^3/min	— cubic feet per minute	5
ft/sec^2	— feet per second squared	4

G

GB	— generator (circuit) breaker	9
GCU	— generator control unit	8
GG	— gas generator	3
gpm	— gallons per minute	5
GS	— Gas Turbine System Technician	1
GSE	— Gas Turbine System Technician (Electrical)	1
GSM	— Gas Turbine System Technician (Mechanical)	1
GT	— gas turbine	5
GTE	— gas turbine engine	3
GTG	— gas turbine generator	2
GTGS	— gas turbine generator set	2
GTM	— gas turbine module	1

H

HF	— high frequency	5
Hg	— mercury	8
HOPM	— hydraulic oil power module	6
hp	— horsepower	7
HP	— high pressure	4
HSS	— high-signal select	8
Hz	— hertz	8

ABBREVIATION/ACRONYM—CONTINUED		CHAPTER
I		
IC	— Interior Communications Electrician	1
IGN	— ignition	7
IGV	— inlet guide vane	4
IMA	— intermediate maintenance activity	12
IMMS	— intermediate maintenance activity maintenance management system	1
in.Hg	— inches of mercury	8
in.H_2O	— inches of water	8
IR	— infrared	4
ITC	— integrated throttle control	9
K		
kΩ	— kilohms	2
kW	— kilowatt	3
L		
lb in.	— pounds-inches	5
lb/min	— pounds per minute	5
lb/sec	— pounds per second	5
lb ft	— pounds-foot	6
LC	— load center	9
LCP	— lighting load center panel	12
LDB	— lighting distribution box	12
LDP	— lighting distribution panel	12

ABBREVIATION/ACRONYM—CONTINUED		CHAPTER
LED	— light emitting diodes	8
LFV	— liquid fuel valve	3
LMET	— leadership, management, effectiveness training	1
L.O.	— lubricating oil	10
LOCOP	— local operating panel (GTG)	2
LOP	— local operating panel	5
LOS	— local operating station	6
LOSCA	— lube oil storage and conditioning assembly	5
LOSIP	— local operating station instrument panel	6
LP	— low pressure	4
LSS	— low signal select	8
LVDT	— linear variable differential transformer	8
LVP	— low-voltage protection	12
LVR	— low-voltage release	12
LVRE	— low-voltage release effect	12

M

MΩ	— megohm	2
mA	— milliampere	3
MBT	— manual bus transfer	12
MDS	— maintenance data system	1
MEASURE	— metrology automated system for uniform recall and reporting	1
MER	— main engine room	11
MFC	— main fuel control	5
mil	— mils = (0.001 in.)	6

ABBREVIATION/ACRONYM—CONTINUED		CHAPTER
MIL STD	— military standard	12
MPU	— magnetic pickup	8
MRG	— main reduction gear	3
μf	— microfarads	12

N

N_1	— speed voltage	8
N_2/N_{pt}	— power turbine speed	6
NAVSEA	— Naval Sea Systems Command	1
NEC	— naval enlisted classification code	1
N_{GG}	— gas generator speed (engine speed)	5
NRCC	— nonresident career course	1
NSTM	— Naval Ships' Technical Manual	1

O

OOD	— officer of the deck	6

P

PACC	— propulsion and auxiliary control console	9
PACEE	— propulsion auxiliary control electronics enclosure	11
PAMCE	— propulsion and auxiliary machinery control equipment	5
PAMISE	— propulsion auxiliary machinery information system equipment	8
PCB	— printed circuit board	9
PCC	— propulsion control console	5
PCS	— propulsion control system	5

ABBREVIATION/ACRONYM—CONTINUED		CHAPTER
PLA	— power level angle	2
PLCC	— propulsion local control console	9
PLCEE	— propulsion local control electronics enclosure	11
PLOE	— propulsion local control equipment	5
PMA	— permanent magnet alternator	8
PMS	— planned maintenance system	1
POT	— potentiometer	7
PP	— power panel	12
pps	— pulse per second	9
PQS	— Personnel Qualification Standard	1
press	— pressure	7
PSEA	— power supply enclosure assembly	10
psid	— pound per square inch differential	5
psig	— pound per square inch gauge	9
PT	— power turbine	2
P_{t2}	— compressor inlet total pressure	5
$P_{t5.4}$	— power turbine total inlet pressure	7
PTO	— power takeoff	2

R

RAM	— random access memory	7
RC	— resistance capacitance	5
RCV	— receive	9
RFI	— radio-frequency interference	5

ABBREVIATION/ACRONYM—CONTINUED		CHAPTER
ROM	— read only memory	7
rpm	— rotations per minute	3
RTD	— resistance temperature detector	3
RTE	— resistance temperature element	3
RTM	— rate training manual	3

S

SAC	— start air compressor	5
SCC	— ship control console	1
SCS	— supervisory control system	10
S/CE	— signal conditioning enclosure	3
SCR	— silicon controlled rectifier	11
SDI	— ship drawing index	1
SHP	— shaft horsepower	5
SIMA	— shore intermediate maintenance activity	2
SPM	— speed phase matching	8
SS	— ship's service	9
SSAS	— ship's service air system	5
SSDG	— ship's service diesel generator	10
SSGTGS	— ship's service gas turbine generator set	8
sup	— supply	7
sync	— synchronize	9
sys	— system	7

T

T_2	— compressor inlet temp	7
$T_{5.4}$	— power turbine inlet temperature (LM2500)	3

ABBREVIATION/ACRONYM—CONTINUED		CHAPTER
TACH	— tachometer	7
temp	— temperature	6
TIT	— turbine inlet temperature (GTG)	3
TLI	— tank level indicator	3
TOPS	— turbine overtemp protection system	8

U

UPS	— uninterruptible power supply	2
UV	— ultraviolet	3

V

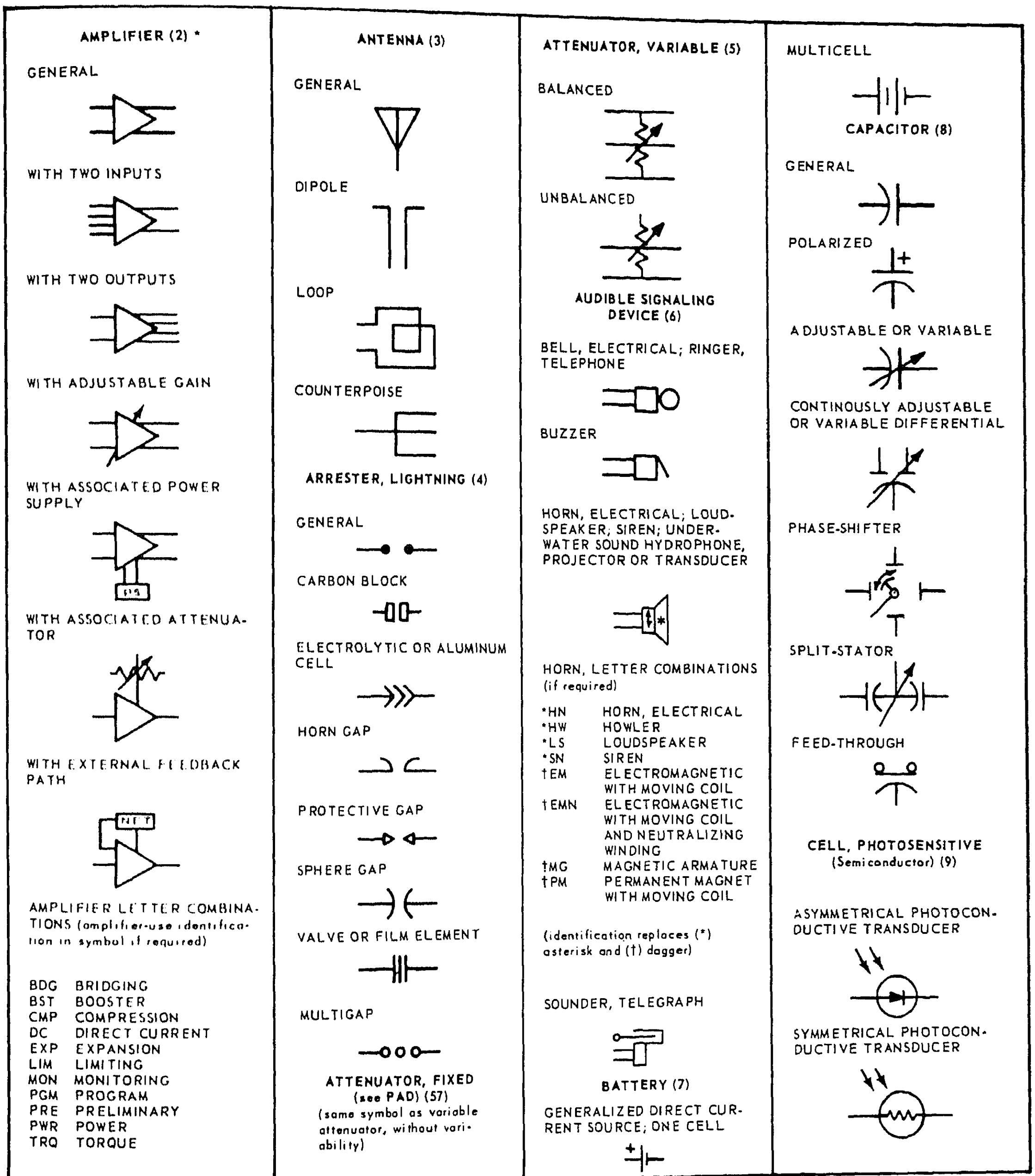
V_{ref}	— reference signal limit (level)	7
VSV	— variable stator vane	4

X

XFMR	— transformer	11
XMIT	— transmit	9

APPENDIX III

ELECTRONICS SYMBOLS



* NUMBER IN PARENTHESES INDICATES LOCATION OF SYMBOL IN MIL-STD PUBLICATION

13.5(179)A

Figure AIII-1.—Electronics symbols.

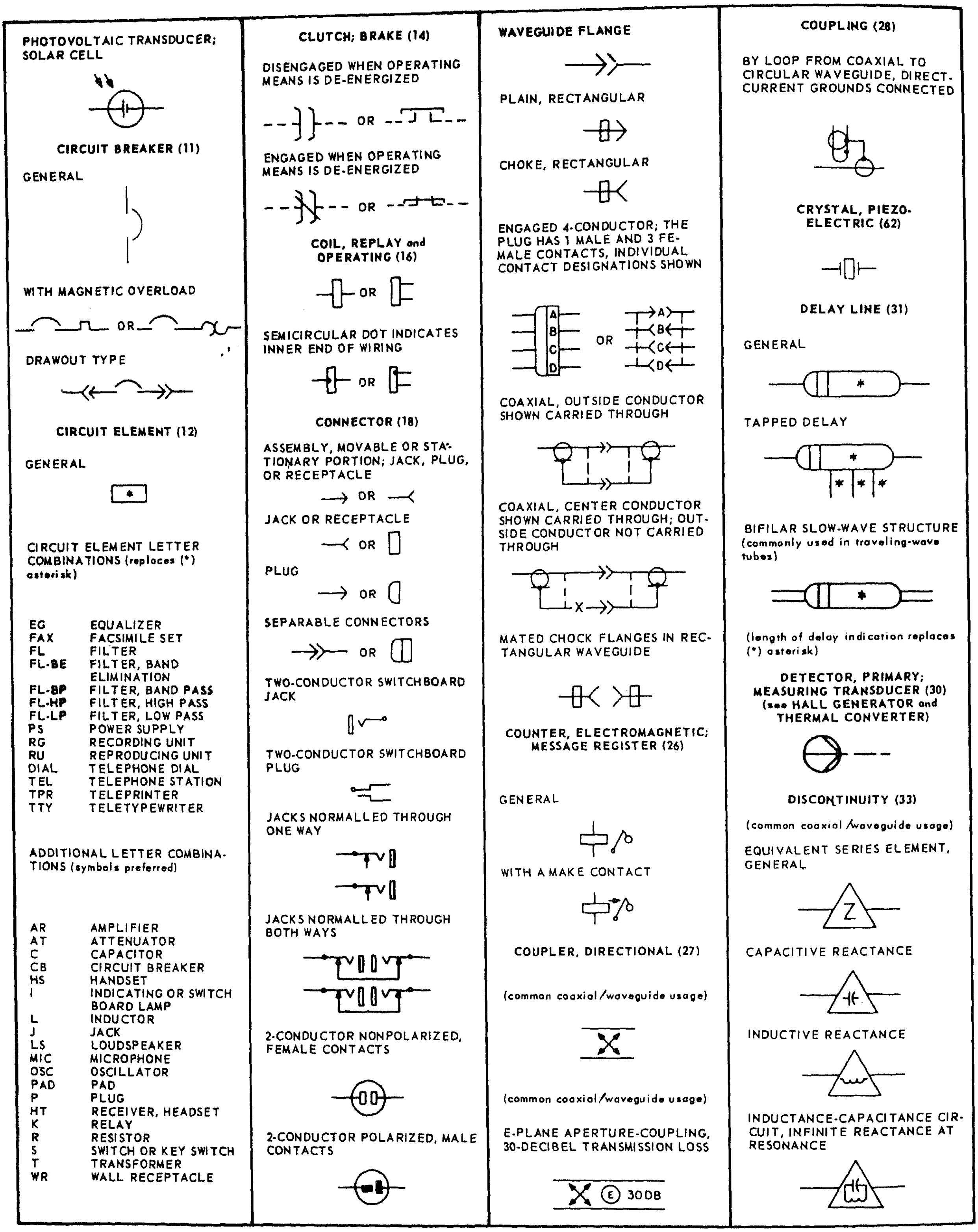


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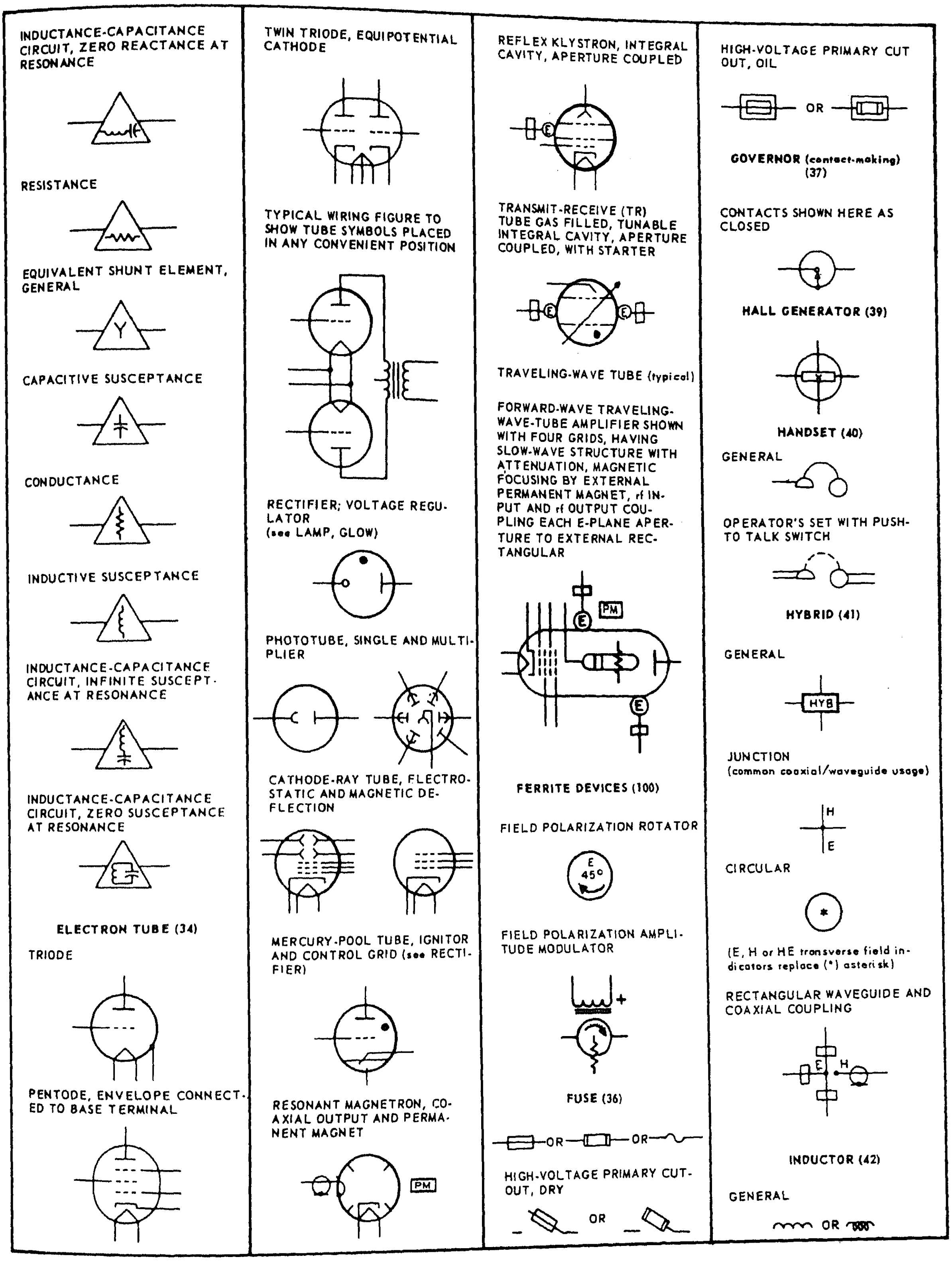
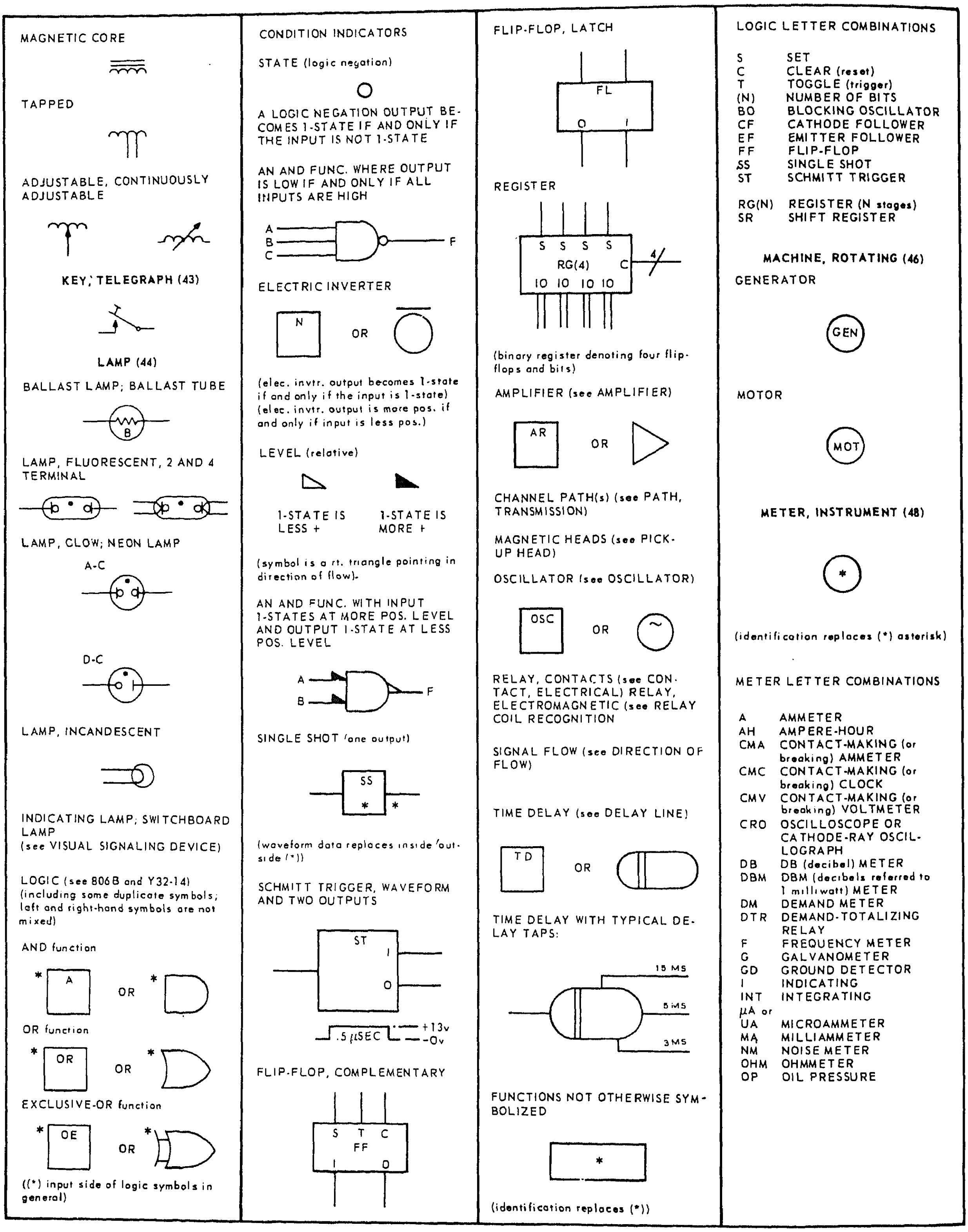
Figure AIII-1.—Electronics symbols—Continued.



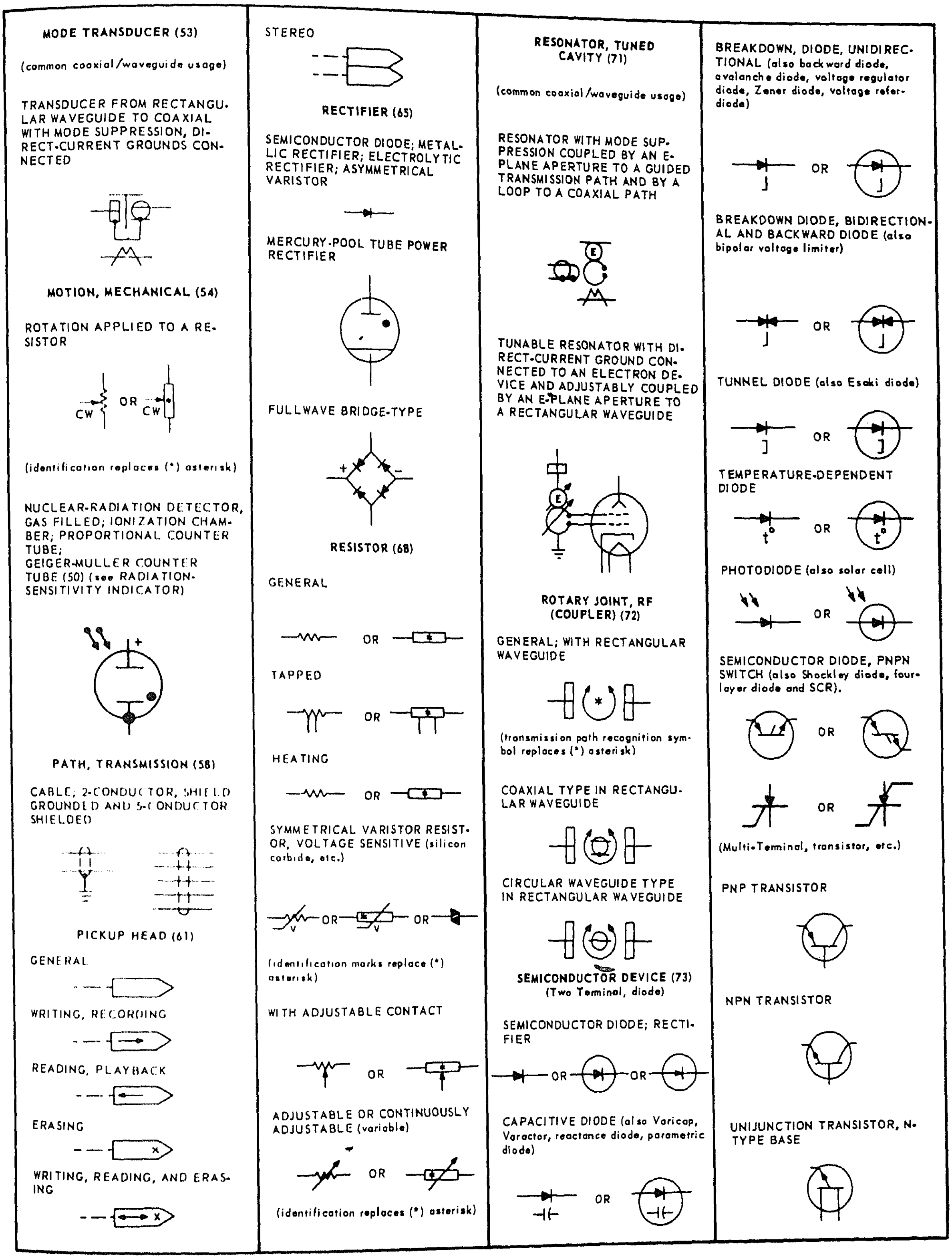
13.5(179)C

Figure AIII-1.—Electronics symbols—Continued.



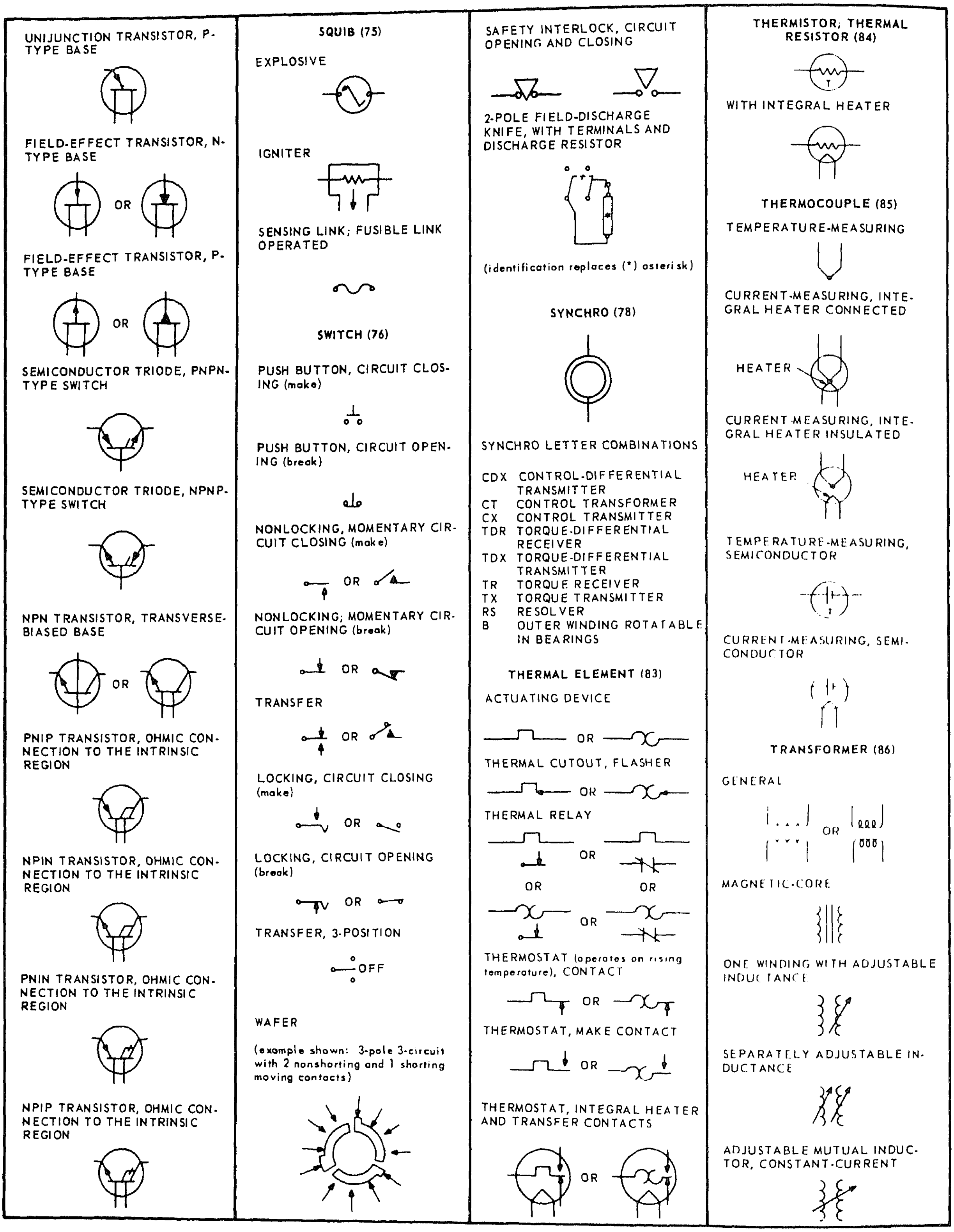
13.5(179)D

Figure AIII-1.—Electronics symbols—Continued.



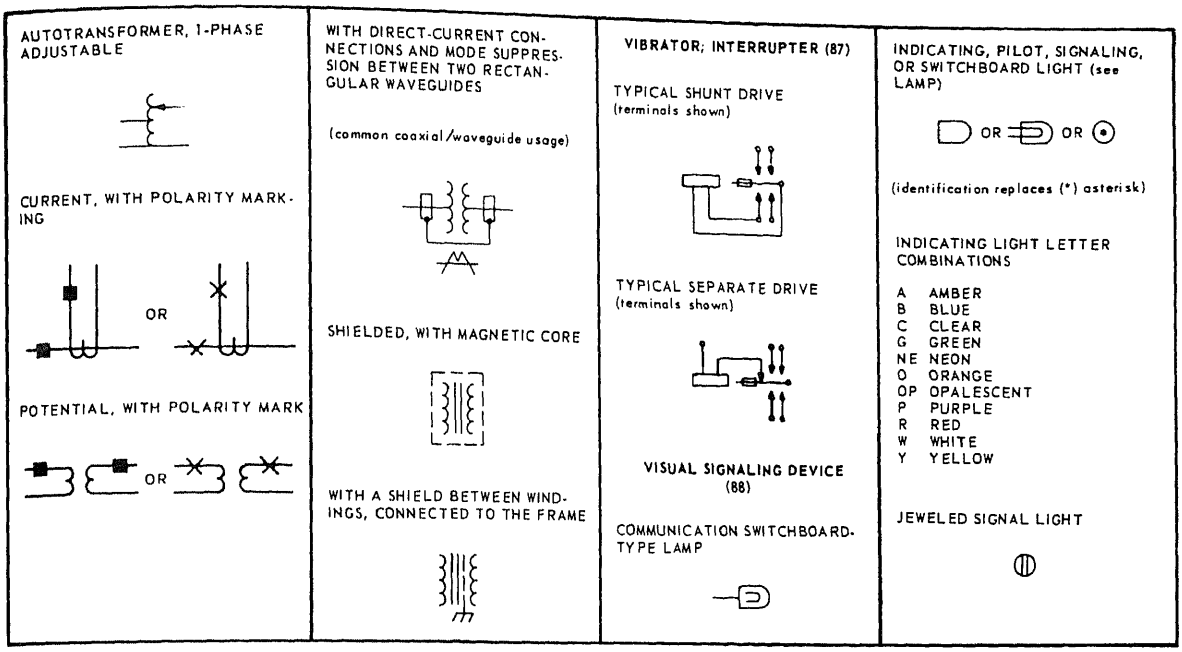
13.5(179)E

Figure AIII-1.—Electronics symbols—Continued.



13.5(179)F

Figure AIII-1.—Electronics symbols—Continued.



13.5(179)G

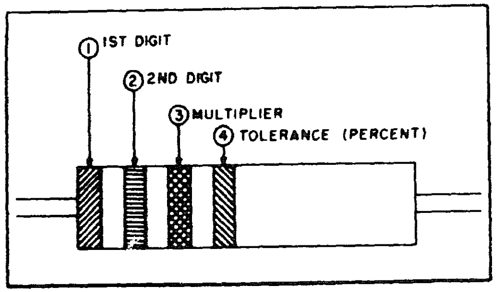
Figure AIII-1.—Electronics symbols—Continued.

APPENDIX IV

ELECTRONICS COLOR CODING

COLOR	1ST DIGIT	2ND DIGIT	MULTIPLIER	TOLERANCE (percent)
BLACK	0	0	1	
BROWN	1	1	10	
RED	2	2	100	
ORANGE	3	3	1,000	
YELLOW	4	4	10,000	
GREEN	5	5	100,000	
BLUE	6	6	1,000,000	
VIOLET	7	7	10,000,000	
GRAY	8	8	100,000,000	
WHITE	9	9	1,000,000,000	
GOLD			.1	5
SILVER			.01	10
NO COLOR				20

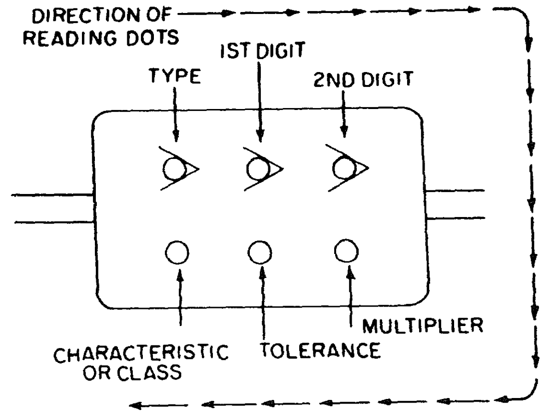
A



B

20.373:.374

Figure AIV-1.—Resistor color code.

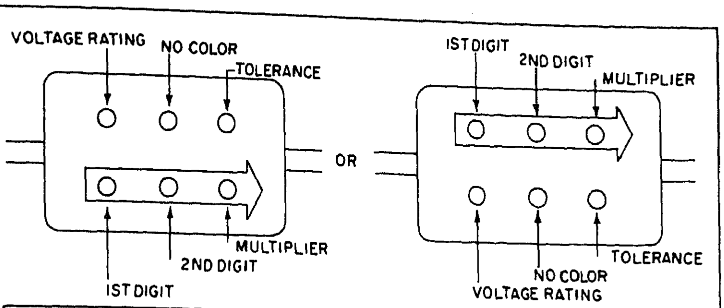


TYPE	COLOR	1ST DIGIT	2ND DIGIT	MULTIPLIER	TOLERANCE (PERCENT)	CHARACTERISTIC OR CLASS
JAN, MICA	BLACK	0	0	1.0		APPLIES TO TEMPERATURE COEFFICENT OR METHODS OF TESTING
	BROWN	1	1	10	±1	
	RED	2	2	100	±2	
	ORANGE	3	3	1,000	±3	
	YELLOW	4	4	10,000	±4	
	GREEN	5	5	100,000	±5	
	BLUE	6	6	1,000,000	±6	
	VIOLET	7	7	10,000,000	±7	
	GRAY	8	8	100,000,000	±8	
EIA, MICA	WHITE	9	9	1,000,000,000	±9	
	GOLD			.1		
MOLDED PAPER	SILVER			.01	±10	
	BODY				±20	

6-DOT COLOR CODE FOR MICA AND MOLDED PAPER CAPACITORS

20.376

Figure AIV-2.—Dot color code for mica and molded paper capacitors.

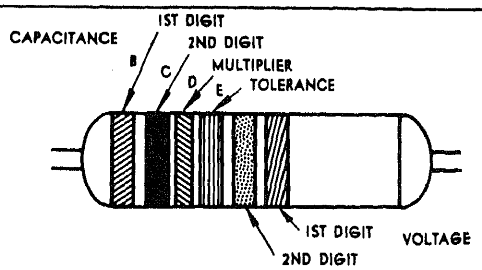


COLOR	I ST DIGIT	2ND DIGIT	MULTIPLIER	TOLERANCE (PERCENT)	VOLTAGE RATING
BLACK	0	0	1.0		
BROWN	1	1	10	±1	100
RED	2	2	100	±2	200
ORANGE	3	3	1,000	±3	300
YELLOW	4	4	10,000	±4	400
GREEN	5	5	100,000	±5	500
BLUE	6	6	1,000,000	±6.	600
VIOLET	7	7	10,000,000	±7	700
GRAY	8	8	100,000,000	±8	800
WHITE	9	9	1,000,000,000	±9	900
GOLD			.1		1000
SILVER			.01	±10	2000
BODY				±20	*

* WHERE NO COLOR IS INDICATED, THE VOLTAGE RATING MAY BE AS LOW AS 300 VOLTS.

20.486

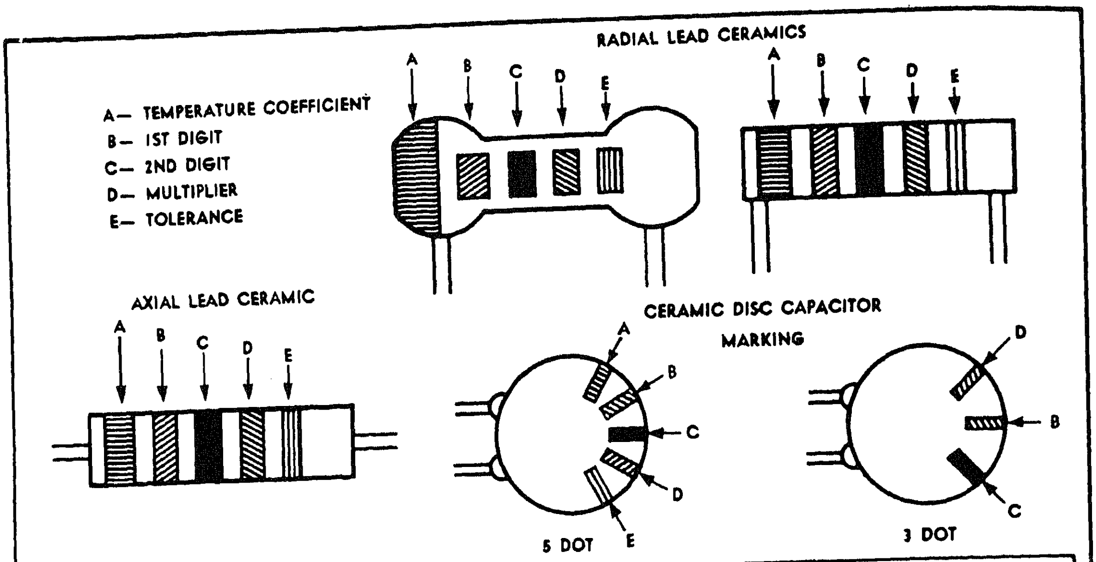
Figure AIV-3.—Dot color code for capacitors (dielectric not specified).



COLOR	CAPACITANCE			TOLERANCE (PERCENT)	VOLTAGE RATING	
	1ST DIGIT	2ND DIGIT	MULTIPLIER		1ST DIGIT	2ND DIGIT
BLACK	0	0	1	±20	0	0
BROWN	1	1	10		1	1
RED	2	2	100		2	2
ORANGE	3	3	1,000	±30	3	3
YELLOW	4	4	10,000	±40	4	4
GREEN	5	5	100,000	± 5	5	5
BLUE	6	6	1,000,000		6	6
VIOLET	7	7			7	7
GRAY	8	8			8	8
WHITE	9	9		±10	9	9

20.487

Figure AIV-4.—Band color code for tubular paper dielectric capacitors.

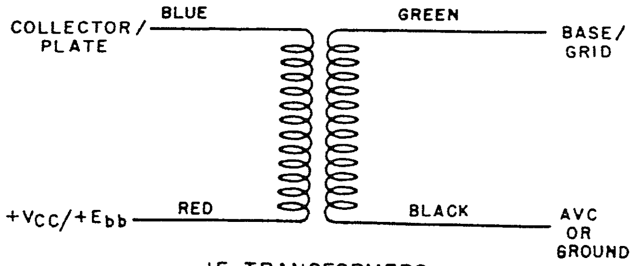


COLOR	1ST DIGIT	2ND DIGIT	MULTIPLIER	TOLERANCE MORE THAN 10 pf (IN PERCENT)	TOLERANCE LESS THAN 10 pf (IN pf)	TEMPERATURE COEFFICIENT *
BLACK	0	0	1.0	±20	±2.0	0
BROWN	1	1	10	± 1		—30
RED	2	2	100	± 2		—80
ORANGE	3	3	1,000			—150
YELLOW	4	4	10,000			—220
GREEN	5	5		± 5	±0.5	—330
BLUE	6	6				—470
VIOLET	7	7				—750
GRAY	8	8	.01		±0.25	+30
WHITE	9	9	.1	±10	±1.0	+120 TO —750 (EIA) +500 TO —330 (JAN)
SILVER						+100 (JAN)
GOLD						BYPASS OR COUPLING (EIA)

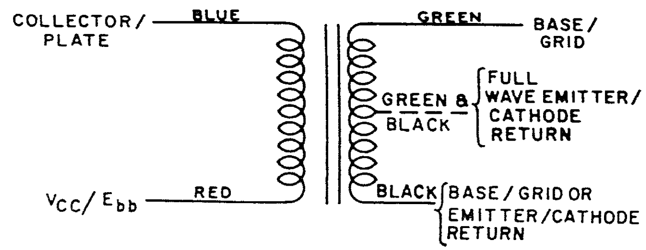
* PARTS PER MILLION PER DEGREE CELCIUS.

20.488

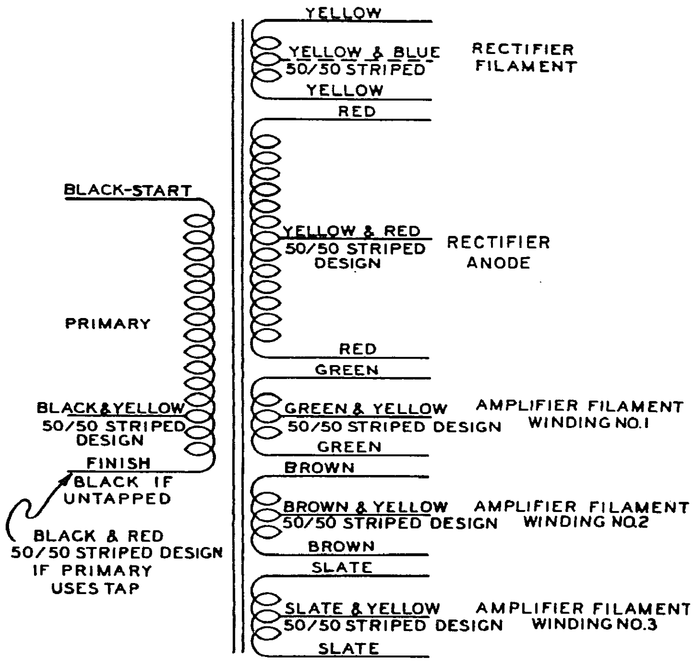
Figure AIV-5.—Color code for ceramic capacitors having different configurations.



IF TRANSFORMERS



INTERSTAGE AUDIO TRANSFORMERS



POWER TRANSFORMERS.

STANDARD COLORS USED IN CHASSIS WIRING FOR THE PURPOSE OF CIRCUIT IDENTIFICATION OF THE EQUIPMENT ARE AS FOLLOWS:

CIRCUIT	COLOR
GROUNDS, GROUNDED ELEMENTS, AND RETURNS	BLACK.
HEATERS OR FILAMENTS, OFF GROUND	BROWN.
POWER SUPPLY $+V_{CC}/+E_{bb}$	RED.
SCREEN GRIDS	ORANGE.
EMITTERS/CATHODES	YELLOW.
BASES/CONTROL GRIDS	GREEN.
COLLECTORS/ PLATES	BLUE
POWER SUPPLY, MINUS	VIOLET (PURPLE).
A.C. POWER LINES	GRAY.
MISCELLANEOUS, ABOVE OR BELOW GROUND RETURNS, AVC, ETC	WHITE.

FOR OTHER ELECTRICAL AND ELECTRONIC SYMBOLS REFER TO MILITARY STANDARD, MIL-STD-15-1A

20.378:.380

Figure AIV-6.—Color code for transformers.

APPENDIX V

METRIC SYSTEM

Table AV-1.—Decimal System Prefaces

THESE PREFIXES MAY BE APPLIED TO ALL SI UNITS

Multiples and Submultiples	Prefixes	Symbols
1 000 000 000 000 = 10^{12}	tera (tĕr′ȧ)	T
1 000 000 000 = 10^{9}	giga (jĭ′gȧ)	G
1 000 000 = 10^{6}	mega (mĕg′ȧ)	M*
1 000 = 10^{3}	kilo (kĭl′ō)	k*
100 = 10^{2}	hecto (hĕk′tō)	h
10 = 10	deka (dĕk′ȧ)	da
0.1 = 10^{-1}	deci (dĕs′ĭ)	d
0.01 = 10^{-2}	centi (sĕn′tĭ)	c*
0.001 = 10^{-3}	milli (mĭl′ĭ)	m*
0.000 001 = 10^{-6}	micro (mī′krō)	μ*
0.000 000 001 = 10^{-9}	nano (năn′ō)	n
0.000 000 000 001 = 10^{-12}	pico (pē′kō)	p
0.000 000 000 000 001 = 10^{-15}	femto (fĕm′tō)	f
0.000 000 000 000 000 001 = 10^{-18}	atto (ăt′tō)	a

*Most commonly used

293.80

Table AV-2.—Metric conversions

Multiply	By	To Obtain
Acres	40.47	Ares
Acres	4,047	Centares
Acres	10	Square chains
Acres	43,560	Square Feet
Acres	4,840	Square Yards
Ares	0.02471	Acres
Ares	100	Centares
Ares	1,076	Square Feet
Ares	119.6	Square Yards
Barrels (U.S., dry)	3.281	Bushels
Barrels (U.S., liquid)	4.21	Cubic Feet
Barrels (U.S., liquid)	31.5	Gallons
Board Feet (1' x 1' x 1'	144	Cubic inches
Cable lengths (U.S.)	120	Fathoms
Cable lengths (U.S.)	720	Feet
Cable lengths (U.S.)	240	Yards
Centares	10.76	Square feet
Centares	1.196	Square Yards
Centimeters	0.3937	Inches
Cubic Centimeters	0.06102	Cubic Inches
Chains	66	Feet
Chains	100	Links
Chains	4	Rods
Cubic Feet	1,728	Cubic Inches
Cubic Feet	0.02832	Cubic Meters
Cubic Feet	0.03704	Cubic Yards
Cubic Feet	6.229	Gallons (British)
Cubic Feet	7.481	Gallons (U.S.)
Cubic Feet	28.316	Liters
Cubic Inches	16.39	Cubic Centimeters
Cubic Inches	0.0005787	Cubic Feet
Cubic Inches	0.003606	Gallons (British)
Cubic Inches	0.004329	Gallons (U.S.)
Cubic Inches	0.01639	Liters
Cubic Meters	35.31	Cubic Feet
Cubic Meters	1.308	Cubic Yards
Cubic Yards	27	Cubic Feet
Cubic Yards	0.7646	Cubic Meters
Cubic Yards	764.6	Liters
Degrees (C.)+ 17.8	1.8	Degrees (F.)
Degrees (F.) −32	0.5556	Degrees (C.)
Degrees	0.01745	Radians
Fathoms	0.00833	Cable Lengths (U.S.)
Fathoms	6	Feet
Fathoms	1.8288	Meters
Feet	30.48	Centimeters
Feet	0.1667	Fathoms
Feet	0.3048	Meters
Feet per Minute	0.01136	Miles per Hour
Feet per Second	0.5921	Knots
Feet per Second	18.288	Meters per Minute
Feet per Second	0.6818	Miles per Hour
Furlongs	10	Chains
Furlongs	660	Feet
Furlongs	40	Rods
Furlongs	220	Yards
Gallons (British)	4,546.1	Cubic Centimeters
Gallons (British)	0.1605	Cubic Feet
Gallons (British)	277.274	Cubic Inches
Gallons (British)	1.2009	Gallons (U.S.)
Gallons (British)	4.546	Liters
Gallons (British)	4	Quarts (British)
Gallons (U.S.)	0.03175	Barrels (liquid, U.S.)
Gallons (U.S.)	3,785.4	Cubic Centimeters
Gallons (U.S.)	0.13368	Cubic Feet
Gallons (U.S.)	231	Cubic Inches
Gallons (U.S.)	0.8327	Gallons (British)
Gallons (U.S.)	3.785	Liters
Gallons (U.S.)	4	Quarts (U.S.)
Grams	15.43	Grains
Grams	0.001	Kilograms
Grams	1,000	Milligrams
Grams	0.03527	Ounces (avoirdupois)
Hands	10.16	Centimeters
Hands	4	Inches
Hectares	2.471	Acres
Hectares	100	Ares
Hectoliters	0.1	Cubic Meters
Hectoliters	26.417	Gallons (U.S.)
Hectoliters	100	Liters
Hogsheads	2	Barrels (Liquid, U.S.)
Hogsheads (U.S.)	63	Gallons (U.S.)
Hundredweights	0.508	Quintals (metric)
Inches	72	Points
Inches	6	Picas
Inches	6	Ems
Inches	12	Ens
Inches	2.54	Centimeters

Table AV-2.—Metric conversions—Continued

Multiply	By	To Obtain
Inches	0.0833	Feet
Inches	1,000	Mils
Inches	0.0277	Yards
Inches of Mercury	0.49131	Pounds per Square Inch
Kilograms	1,000	Grams
Kilograms	2.2046	Pounds (Avoirdupois)
Kiloliters	1	Cubic Meters
Kiloliters	1.308	Cubic Yards
Kiloliters	264.18	Gallons (U.S.)
Kiloliters	1,000	Liters
Kilometers	4.557	Cable Lengths
Kilometers	3,280.8	Feet
Kilometers	39,370	Inches
Kilometers	1,000	Meters
Kilometers	0.5396	Miles, Nautical
Kilometers	0.62137	Miles, Statute
Kilometers	1,093.6	Yards
Knots	1.1516	Statute Miles per Hour
Knots	1.688	Feet per Second
Leagues, Nautical	25.33	Cable Lengths
Leagues, Nautical	5.5597	Kilometers
Leagues, Nautical	3	Miles, Nautical
Leagues, Statute	4.8280	Kilometers
Leagues, Statute	3	Miles, Statute
Links	7.92	Inches
Liters	1,000	Cubic Centimeters
Liters	61.025	Cubic Inches
Liters	0.21998	Gallons (British)
Liters	0.26418	Gallons (U.S.)
Liters	0.8799	Quarts (British)
Liters	0.908	Quarts (U.S., dry)
Liters	1.0567	Quarts (Liquid, U.S.)
Meters	100	Centimeters
Meters	0.001	Kilometers
Meters	1.0936	Yards
Meters	3.281	Feet
Meters	39.37	Inches
Meters	1,000	Millimeters
Meters	1.0936	Yards
Meters per Minute	0.0547	Feet per Second
Meters per Second	2.237	Miles per Hour
Microns	0.001	Millimeters
Miles, Nautical	8.44	Cable Lengths
Miles, Nautical	6,076.1	Feet
Miles, Nautical	72,963	Inches
Miles, Nautical	1.8532	Kilometers
Miles, Nautical	1,853.2	Meters
Miles, Nautical	1.1508	Miles, Statute
Miles, Nautical	1	Minutes of Latitude
Miles, Nautical	2,026.8	Yards
Miles per Hour (Statute)	88	Feet per Minute
Miles per Hour (Statute)	1.467	Feet per Second
Miles per Hour	0.8684	Knots
Miles, Statute	7.33	Cable Lengths
Miles, Statute	5,280	Feet
Miles, Statute	8	Furlongs
Miles, Statute	63,360	Inches
Miles, Statute	1.6093	Kilometers
Miles, Statute	1,609.3	Meters
Miles, Statute	0.8689	Miles, Nautical
Miles, Statute	1,760	Yards
Millier (See Tons – Metric)		
Milliradians	206.265	Seconds of Arc
Mils	0.001	Inches
Myriameters	10	Kilometers
Ounces (avoirdupois)	28.3495	Grams
Pint (Liquid, U.S.)	4	Gills (U.S.)
Pint (Liquid, Br.)	4	Gills (British)
Pint (Liquid, Br.)	0.56825	Liters
Pint (Liquid, U.S.)	0.4732	Liters
Pounds (avoirdupois)	7,000	Grains
Pounds (avoirdupois)	453.59	Grams
Pounds (avoirdupois)	0.4536	Kilograms
Pounds (avoirdupois)	16	Ounces
Pounds (avoirdupois)	1.2153	Pounds (troy)
Pounds (troy)	0.8229	Pounds (avoirdupois)
Pounds per Square Inch	2.03537	Inches of Mercury
Quart (British)	1.1365	Liters
Quart (British)	2	Pints (British)
Quart (Liquid, U.S.)	0.9463	Liters
Quart (U.S.)	2	Pints (U.S.)
Quintals (Metric)	1.97	Hundredweights
Quintals (Metric)	100	Kilograms

Table AV-2.—Metric conversions—Continued

Multiply	By	To Obtain	Multiply	By	To Obtain
Radians	57.30	Degrees	Square Miles, Statute	259	Hectares
Rods	16.3	Feet	Square Miles, Statute	2.59	Square Kilometers
Rods	25	Links	Square Yards	0.8362	Centares
Square Centimeters	0.1550	Square Inches	Square Yards	9	Square Feet
Square Feet	0.0929	Centares	Square Yards	1,296	Square Inches
Square Feet	929	Square Centimeters	Tons (Long)	1.016	Metric Tons
Square Feet	144	Square Inches	Tons (Long)	2,240	Pounds (Avoir-dupois)
Square Feet	0.1111	Square Yards			
Square Inches	6.452	Square Centimeters	Tons (Metric) (Millier)	1,000	Kilograms
Square Inches	0.006944	Square Feet			
Square Kilometers	100	Hectares	Tons (Metric) (Millier)	2,204.6	Pounds (Avoir-dupois)
Square Kilometers	0.3861	Square Miles (Statute)			
			Tons (Short)	0.9072	Metric Tons
Square Meters (See Centares)			Tons (Short)	2,000	Pounds (Avoir-dupois)
Square Miles, Statute	640	Acres	Yards	91.44	Centimeters
Square Miles, Statute	25,900	Ares	Yards	0.9144	Meters

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